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Maintaining European dairy cattle in the Near East

by R.H. Ansell

In recent times considerable numbers of *Bos taurus* dairy cattle have been introduced into many countries in the Near East where the prevailing species is *Bos indicus*. Since the climate in this region differs markedly from that in the natural habitat of the European breeds, the question has frequently been raised as to whether climatic factors have been responsible for the often disappointing results obtained from *Bos taurus* cattle. Alternatively, are these poor results due to inadequate management and feeding and lack of knowledge of the requirements of exotic cattle?

This article reviews the results of a three-and-a-half-year study (Ansell, 1974) conducted in the United Arab Emirates, where the summer climate is extremely inimical to dairy production. The study was made on British Friesian cattle, which are not noted for their heat tolerance.

In view of the relative success achieved in maintaining high production under such harsh climatic conditions, this article has been written for the benefit of those who plan to introduce high-yielding European cattle into other parts of the Near East or to countries with similar climates. It describes some of the problems likely to be encountered and the steps that can be taken to alleviate the stresses imposed on the cattle.

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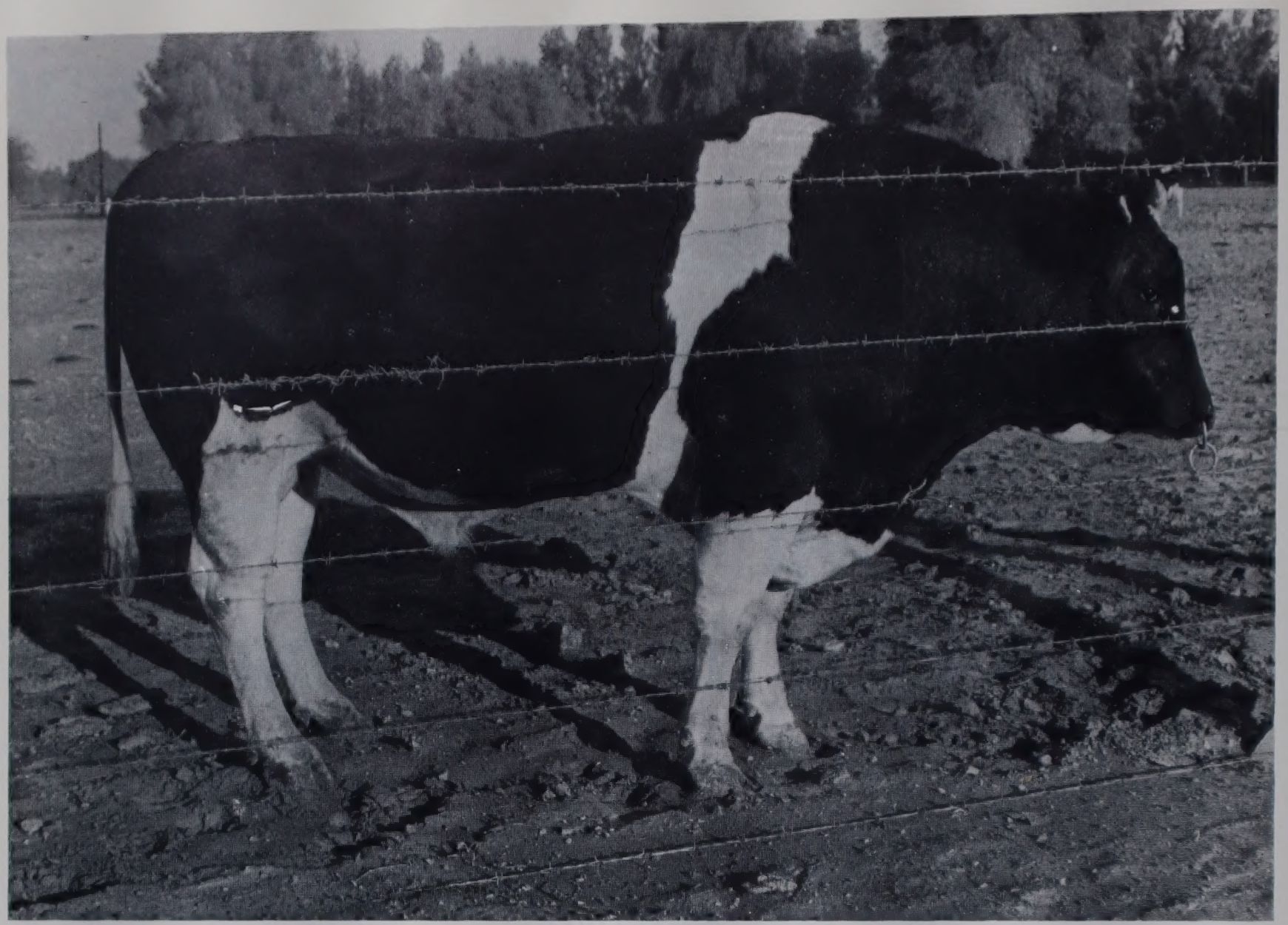
Physiological considerations

Body heat in cattle is largely the product of the exothermic physical and chemical reactions within the animal and the absorption of heat by radiation and conduction from the environment. The dissipation of body heat is achieved by radiation, conduction and evaporation of moisture. Other minor methods of acquiring and dissipating heat are the voidance of faeces and urine, raising ingesta to body temperature, and endothermic reactions. But these can be ignored in the context of animal management, with one exception: the ingestion of cold water, which could be of some significance.

Evaporation of moisture, whether from the skin or lungs, is a major factor in heat dissipation, and it is unfortunate that cattle, in particular the European breeds, are less well endowed with sweat glands than heat-tolerant mammals such as man.

Evaporation is of course dependent on the humidity of the air and the wind velocity over the evaporating surface. Although this is a controversial subject and involves complex physical concepts, it can be safely assumed that relative humidity readings as taken from a wet and dry bulb thermometer can be used as a guide to the evaporative capacity of the air. It is this major dependence on evaporation for heat dissipation which makes high relative humidities — in association with high temperatures — so critical in producing heat stress. Various formulae have been devised combining humidity and temperature to produce a "heat index." Perhaps the most promising of these



Friesian bull in fine condition after a severe summer in the United Arab Emirates

is that of Bianca (1962): heat index = dry bulb °C × 0.35 + wet bulb °C × 0.65. But neither this nor other formulae have been fully confirmed experimentally, although they do provide a crude assessment of comparative climatic severity when the introduction of exotic stock to unfavourable climates is being considered.

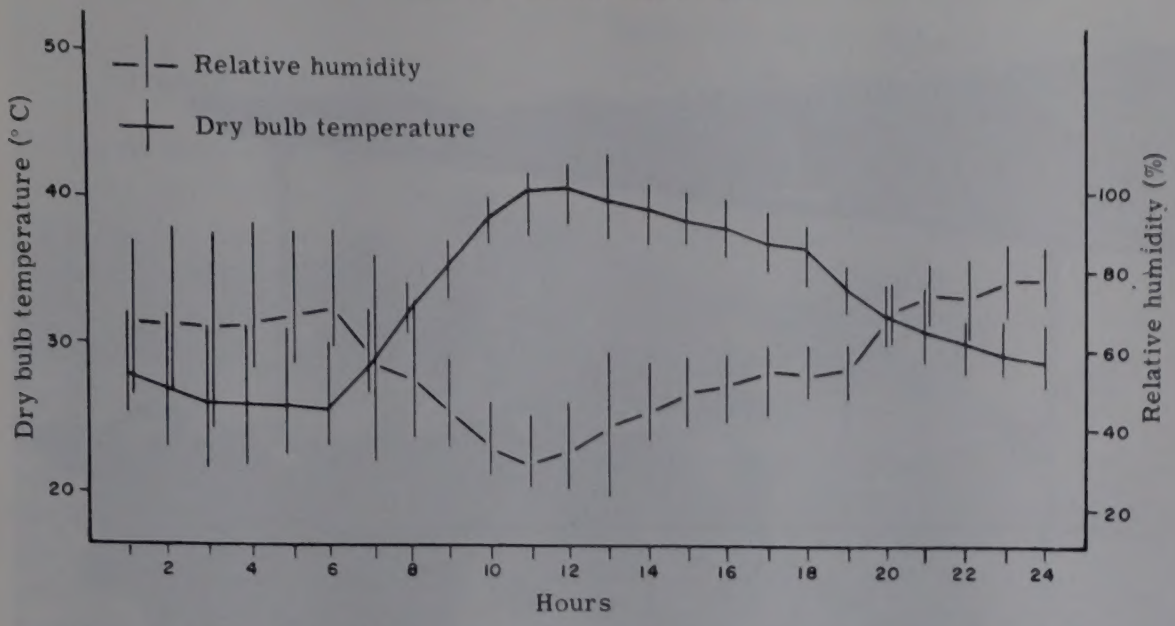
Conduction and radiation are simpler concepts of heat dissipation than evaporation. They are dependent on environmental temperatures and on the surface area/body weight ratio of the animal, i.e. an animal with a large surface area in relation to its bulk (e.g. a bat) can dissipate heat by these means more easily than one with a low surface area to body weight ratio. It has often been assumed in this connexion that the large dewlap, pendulous sheath, large ears and hump of Asiatic cattle which contribute to their increased surface area also contribute to heat tolerance. However, this is not necessarily the case, since experimental surgical excision of these organs has shown that the heat tolerance of the animals so treated is unaffected. This observation may be of some consequence in that it would be useless to select smaller animals from within a breed for introduction into hot climates solely in the belief that their surface area/body weight ratio would result in increased heat tolerance. The effect of such selection, if any, might be insignificant in relation to that of other factors.

An important aspect of heat dissipation is the diurnal variation in dry bulb temperature. Cattle can build up heat within their bodies to a considerable degree during the day without adverse effects if the night temperatures are sufficiently low to allow for its dissipation. But high sustained body temperatures are destructive.

A detailed knowledge of the climate of the area in question is therefore essential for assessing the heat stress likely to be encountered by animals. Monthly means of maximum and minimum temperatures are of little use; diurnal variations of temperature and humidity and their duration are of much greater significance. The results obtained in the United Arab Emirates suggest that on grounds of climatic factors alone, there are likely to be very few areas in the Near East where European breeds cannot be maintained successfully.

Figures 1 and 2 illustrate the severity of the climatic conditions experienced in the United Arab Emirates; they are near the upper limit of tolerance of Friesian cows in milk. It should be noted that the temperatures were recorded in well-shaded sites; they should not be equated with temperatures recorded in the standard

Figure 1. **Method of depicting climatic stress in British Friesian cattle in the United Arab Emirates, June 1972** [1]



SOURCE: Work done by the author at Digdaga, Ras Al Khaimah, United Arab Emirates in June 1972.

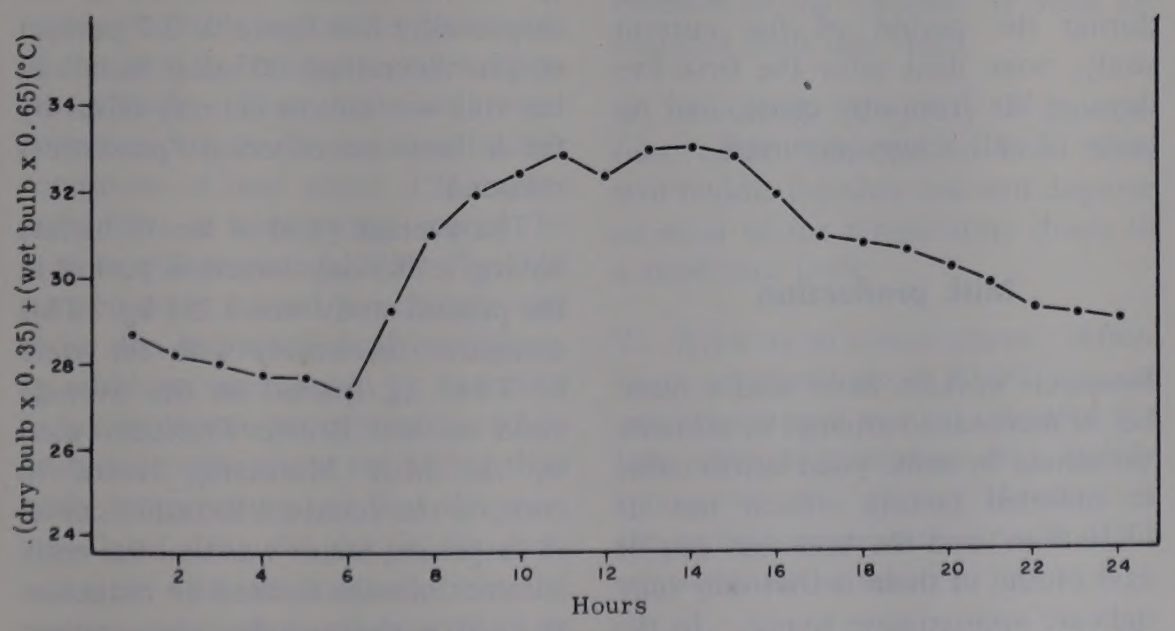
[1] The curves represent the arithmetic mean of once weekly readings taken at hourly intervals. The length of the vertical bars gives the range of the readings.

"Stevenson screen" type meteorological box which, during the hours of sunlight, gives much higher readings.

Effect of diet

The results of climatic chamber experiments conducted at the University of Missouri in the United States, and elsewhere, suggested that depression of appetite is a significant factor in reducing the milk yields of animals subjected to high environmental temperatures. These results were not corroborated in the United Arab Emirates study, since it was possible to maintain the animals on a constant diet throughout winter and summer with a ration that maintained both yield and body condition. This diet consisted of: a maintenance ration of 20.5 kg freshly cut alfalfa, 3.2 kg compounded dairy nuts, 1.8 kg bran, 14 g mineral and vitamin supplement and 57 g dicalcium phosphate; and a production ration of 1.8 kg of compounded dairy nuts per 4.5 kg of milk.

Figure 2. **Method of depicting climatic stress in British Friesian cattle in the United Arab Emirates, 22 June 1972** [1]



SOURCE: Work done by the author at Digdaga, Ras Al Khaimah, United Arab Emirates in June 1972.

[1] The curve represents hourly readings of relative humidity and ambient temperature taken on one day and converted according to the formula of Bianca (1962). It depicts a pattern that approaches the upper limit of tolerance of fully acclimatized Friesian cows in milk.

No grazing was available to the animals, and salt was not included in the ration since the salinity of the drinking water was very high and salt was in any case refused when offered.

This diet proved very satisfactory and resulted in a Compton metabolic profile well within standard limits. It is possible that the severe depression of appetite reported in the climatic chamber studies (which was not encountered to any great degree in the study) may have been a psychosomatic effect on the animals resulting from the close confinement inherent in chamber experiments. However, it was observed that the animals in the study took considerably longer to consume the ration in the summer months when conditions became extreme.

Reproduction

The suppression of spermatogenesis and early foetal reabsorption (Stott and Williams, 1962) are well documented under high temperature regimes. These phenomena were amply demonstrated in the first year of the United Arab Emirates study in that no successful conceptions took place between the months of June and October, although libido and manifestations of heat were not seriously affected. Two points are worthy of note in this connexion: spermatogenesis can be impaired for as long as nine weeks after exposure to heat (Johnston, Naelapaa and Frye, 1963); and oestrous periods tend to be "quiet" and short, thus making heat detection difficult if AI is to be practised.

It was also found that calving in the hot season subjected the animals to unacceptable stress conditions. Gestation periods were shorter by approximately 10 to 14 days for summer calvings, birth weights of calves were significantly reduced, and calves born during the height of the summer were found to be as much as 56 days premature in some cases. The shortened gestation periods adversely affected the dry periods prior to parturition. A high proportion of

Palm leaf shades are simple and cheap to construct

primary inertia was also encountered in the herd studied, but its relation to season of calving could not be demonstrated. It does not necessarily follow that all of these manifestations will occur in more moderate temperatures, but the possibility nevertheless remains.

Thus seasonal calving and close supervision of parturition are essential under climatic conditions as extreme as those encountered in the United Arab Emirates. Under such conditions, services should be limited to the months of February, March and April if neither conception nor parturition are to occur during the summer months.

Calf rearing

Great care must be taken during the first 10 days of life of the calf because its thermoregulatory mechanism appears to be defective during this period, and it may develop extreme hyperthermia and die if artificial cooling is not provided.

For premature calves, this critical phase extends over a longer period. But once the calves have passed it, they tolerate heat stress well and pose few problems. Of 94 calves born during the period of the current study, none died after the first five days of life from any cause, and no cases of calf scours occurred.

Milk production

Research workers have used a number of methods to attempt to estimate variations in milk yield attributable to different factors. Each has its limitations, and the best that can be said of any of them is that they only indicate approximate trends. In the United Arab Emirates study the depression of milk yield attributable to the climate was estimated by reference to the standard lactation curve constructed on the basis of the formula devised in the United Kingdom by the Milk Marketing Board (1969/70). On this basis it was found that the depression of yield attributable to the hot season amounted to the surprisingly low figure of 2.7 percent of the theoretical 305-day lactation, but this was almost entirely offset by the hitherto unsuspected "post-stress rebound".

The average yield of the 19 heifers having a 305-day lactation period in the present study was 3 253 kg. This compares favourably with the yield of 3 842 kg quoted as the average yield of 859 British Friesians used by the Milk Marketing Board to compile the standard lactation curve. A surprising factor was that the early summer months showed no reduction in yield; sometimes the reverse occurred. But toward the end of summer "fatigue" seemed to set in, and most

of the reduction occurred at that time.

Health and disease

Problems were experienced with hoof necrosis attributable to the animals standing for long periods on sawdust moistened with urine and dung. This is of relevance to areas where bedding is in short supply and where animals must be confined on hard standings for long periods. It appears that moist bedding at temperatures approaching bacterial incubation levels can be destructive to hoof tissues.

No statistically significant difference was detected between the incidence of mastitis in summer and winter; the level of incidence was within reasonable limits.

An important health hazard was the pathogenicity of *Theileria annulata*, which is endemic throughout most of the Near East. Whereas mortality from this cause is comparatively low among indigenous cattle, it is very high among *Bos taurus* breeds. Tick control must therefore be complete and provision must be made for dipping or power spraying; hand spraying is usually inadequate.

No other special disease problems attributable to the unfavourable climate were encountered during the three and a half years covered by the study. It may therefore be concluded that if normal prophylactic medicine is practised, the incidence of infectious diseases should pose no difficulty. Nevertheless, it would be highly desirable to monitor the health of the herd by taking rectal temperatures daily. Since high body temperatures are to be expected under conditions of heat stress, it is imperative that a continuous record be kept to differentiate between the high temperatures caused by climate and those due to pathological conditions. In addition, care should be exercised in taking thermometer readings when ambient temperatures are higher than body temperatures, so that the mercury level does not rise in the thermometer after its removal from the rectum. A cotton swab soaked in alcohol is useful under these conditions.

Signs of heat stress

When the upper limit of heat tolerance is approached, cattle show some unmistakable and often alarming stress symptoms:

1. *Open mouth breathing.* This is indicative of very advanced stress; the head is extended, the mouth held open, and profuse salivation takes place.

2. *High respiratory rates.* These may be in the 100 to 120 range, but surprisingly they can be tolerated daily for long periods without causing any apparent symptoms of respiratory alkalosis.

3. *Second phase breathing.* This is a phenomenon first recorded by Beakley and Findlay (1955). At rectal temperatures of approximately 41.8°C there is a sudden drop in respiratory rate with a concurrent increase in tidal volume. This phase is also a symptom of advanced stress and should not be allowed to continue.

4. *Body splashing.* Strenuous efforts may be made by animals to paw water back onto their bodies from water troughs or to beat the water with their heads.

5. *Refusal to lie down.* This is a common phenomenon. Usually all the animals in the herd will stand for long periods when they would normally be expected to lie down; ablation of the "elbows" is often associated with this stage.

6. *Huddling.* Contrary to expectation, cattle subjected to heat stress will huddle together and will disperse as soon as the temperature drops to a moderate level.

7. *High rectal temperatures.* Afternoon temperatures of 40.5°C are not uncommon and can be tolerated for long periods providing that nightly remissions take place. However, if the rectal temperature exceeds 41°C, steps should be taken to reduce it.

Most of the above symptoms are valuable clinical indications of the degree of stress being experienced by cattle, and could serve as a guide to the time when steps to alleviate the stress must be taken. It may be noted in this connexion that lactating and heavily pregnant animals have a lower degree of heat tolerance than non-lactating animals. One *Bos indicus* animal in the study demonstrated its superior heat tolerance by lying happily in the sun with a barely perceptible respiratory rate of 8 to 10, when respiratory rates among *Bos taurus* cattle were in the region of 120. However, its growth curve was markedly depressed, and it could best be described as being almost in a state of aestivation.

Amelioration of climate

Although the foregoing may appear to be a formidable list of woes likely to be encountered by cattle under adverse climatic conditions, in practice most of them were encountered only when deliberate efforts were made to refrain from taking steps to mitigate climatic stress. When such steps were taken, the herd remained remarkably trouble-free and tolerated the conditions of the Persian Gulf littoral very well. The more important methods adopted are listed below.

Showering. A variety of methods for cooling dairy cattle were tried:

(*a*) complete air conditioning, (usually very expensive);
(*b*) desert coolers, which rely on a forced draught over a wetted surface;
(*c*) the provision of cooled drinking water;
(*d*) breathing hoods supplied with a cooled air supply;
(*e*) high-speed fans.

However, probably the most cost-effective method consists of providing the animals with an artificial sweating mechanism to equate them with the freely sweating, heat-tolerant mammals. This can be done in a number of ways: the easiest is to invert a revolving domestic garden sprinkler on to the ceiling of a concrete-floored cattle shed. It was found that the

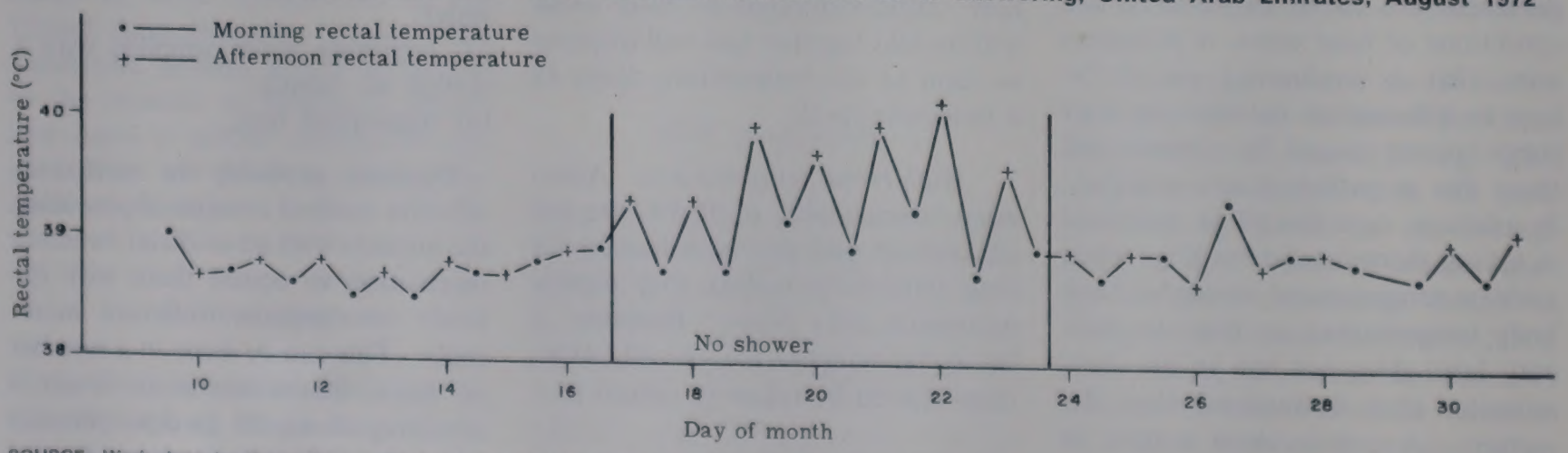
Feeding yard constructed of pipe and galvanized sheeting. Note venturi arrangement at apex of roof

cattle then formed an outward-facing circle at the periphery of the spray, and that a few hours free access to this in the afternoons reduced otherwise elevated body temperatures to normal limits, even in the relatively high humidities of the Gulf. The temperature of the water is to all intents and purposes immaterial since the latent heat of evaporation is utilized. The effectiveness of this method is amply demonstrated in Figure 3, which shows the mean rectal temperature of 21 cows with and without access to showering. The advantage of this method is that energy is not expended in lowering the temperature of large masses of air (as in desert coolers or air conditioners) which may not come into contact with the animal. However, a reasonable supply of water is necessary, but no more than is usually required if dairying is to be practised. Similarly, the temperature of an individual animal may be reduced dramatically by soaking it with water. It is not necessary to play a continuous stream of water over the animal, although if one wetting of the coat is insufficient, the coat may be re-wetted when dry. This effect is shown in Figure 4.

Shelter engineering. The provision of properly constructed shade is essential in tropical latitudes. A Friesian cow confined without shade in the temperatures and humidities of the Persian Gulf will reach a stage of lethal hyperthermia within a few hours.

Ideally, shelters should have high insulating properties and should be extensive enough to eliminate much of the radiation from the sky. They should have a low radiation coefficient, and as a general rule should be at least 3 metres high. A large, leafy, non-deciduous tree approaches the ideal. Thatch from palm leaf, straw or grass is a very satisfactory material. Asbestos cement, galvanized iron or aluminium are less satisfactory but are usually the most

Figure 3. **Mean rectal temperature of 21 cows with and without access to showering, United Arab Emirates, August 1972** [1]



SOURCE: Work done by the author at Digdaga, Ras Al Khaimah, United Arab Emirates in August 1972.

[1] Readings were taken from cows with access to an overhead sprinkling system between 12.00 and 16.00 hrs in a climate similar to that depicted in Figure 1.

commonly available materials. Their defects may be offset to a certain extent by making their surfaces reflecting (with silver or white paint), and by constructing the shelters properly. A highly effective but costly method of construction with these materials is to have a two-skin roof with an air gap of not less than 12 cm between the two skins. This air gap should have free access to the outside at the apex. If only a single skin of these materials can be afforded, the pitch of the roof should be made reasonably steep (not less than 20°); this will accelerate the upward movement of hot air layers adjacent to the undersurface. In addition, it should be as high as can be conveniently constructed, recognizing however that the extent to which a shadow moves is in direct proportion to the height of the shade. Thus when high shelters are designed, care must be exercised to ensure that the shadow is not cast outside the animals' quarters. Air gaps at the apexes of buildings for the exhaustion of hot air can be enhanced by constructing a flat or curved "lid" over the gap in order to produce a venturi effect.

In most areas of the Near East low wind velocities are a problem. But where high hot winds do occur, slatted walls or fences reduce the velocities considerably and interfere little with normal ventilation. The width between slats may be varied to suit prevailing wind speeds, but equal spacings are often a satisfactory compromise.

Feeding. Since a specific heat increment is associated with feeding, it is necessary to arrange feeding schedules to correspond with the cooler periods of the day — usually at night and in the early morning. Milking times should be organized in a similar fashion, since concentrates are normally offered at these times. The interval between milkings should be as wide as can be consistent with these factors.

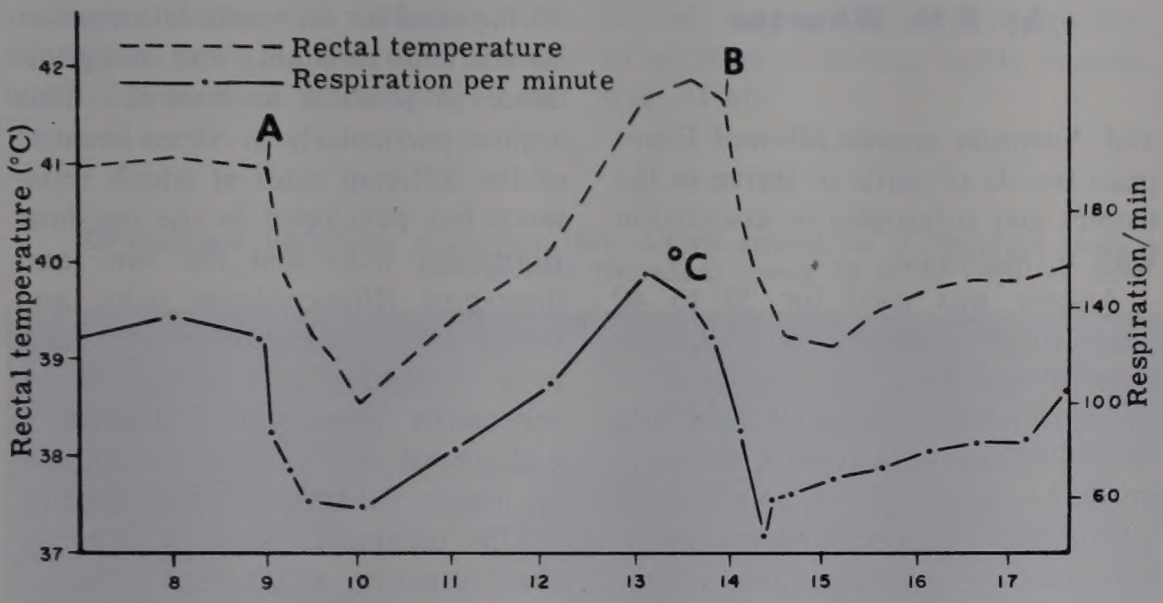
Zero grazing systems in extreme climatic conditions have a decided advantage in that energy expenditure and heat production due to walking are kept to a minimum. However, if grazing is practised, the distance walked should be kept to a minimum and the grazing confined to the hours of darkness.

Local conditions will of course dictate what diets are available, but experimental work has confirmed that more heat is produced from roughages for a given nutrient intake than from concentrates, and that succulent herbage is more readily ingested under high ambient temperatures than dry ligneous material.

Water. Water should, of course, be available at all times. The consumption of water by European cattle under heat stress may be more than twice that in their natural habitat.

Chilled drinking water is welcomed by stock. It undoubtedly reduces the heat load of the animals considerably, but the medium- and long-term effects of this practice on ruminant digestion have not been fully explored. This method of climatic alleviation must therefore be approached with caution.

Figure 4. **Effect of wetting on the respiratory rate and rectal temperature of a six-day-old calf, 26 August 1971** [1]



SOURCE: Work done by the author at Digdaga, Ras Al Khaimah, United Arab Emirates in August 1972.
[1] Intermittent hosing begins at Point A. Point B represents one soaking only. At Point C, the respiratory rate has dropped with increased rectal temperature (second phase breathing).

Conclusion

The principal conclusion of this study is that if appropriate steps are taken to mitigate the effects of climate and a high level of management practices is maintained, there appears to be no reason why high ambient temperatures and humidities should be inimical to successful dairy development with European breeds in the Near East.

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TICK-BORNE LIVESTOCK DISEASES AND THEIR VECTORS

5. Acaricide resistance and alternative methods of tick control

by R.H. Wharton

The resistance of ticks to acaricides poses an increasing threat to livestock production in many countries because of their almost complete dependence on acaricides for tick control. Resistance has led to instability and increased costs in areas where the one-host cattle ticks *Boophilus microplus* and *B. decoloratus* have acquired resistance to a variety of toxic chemicals. The point has now been reached where such resistance must be expected in these ticks within five to 10 years of the introduction of any new type of acaricide, unless control practices are changed. In Africa, resistance could ultimately lead to a much greater dislocation of the cattle industry than elsewhere because of the more serious problems caused by the three-host ticks (*Rhipicephalus, Amblyomma* and *Hyalomma*) and the diseases they transmit.

Prior to the development of arsenic in the 1890-1910 period, cattle owners in North America, Latin America, Australia and Africa had no practical method of limiting tick numbers on their cattle. In the United States arsenic provided the opportunity for cattlemen in the southern states to retain their markets in the north through a campaign that eventually succeeded in eradicating *B. annulatus*; in Africa the frequent application of arsenic permitted the development of highly productive cattle industries, while in Central and South America and Australia arsenic allowed European breeds of cattle to thrive in the tropics and subtropics in association with *B. microplus*.

Arsenic was used for 30 to 40 years before resistance developed in *Boophilus* ticks. This occurred at about the same time prior to World War Two in Africa, Australia and South America. The organochlorines DDT, BHC (lindane) and toxaphene (campheclor) overcame the arsenic resistance problem during the 1945-55 period, and for the first time provided cattle owners with chemicals that were highly toxic to ticks and were safe and easy to use.

The organochlorines were supplemented or replaced by the organophosphorus (OP) and carbamate chemicals in the 1955-70 period. These in turn were replaced in some areas by formamidines and related chemicals after 1970. These rapid changes were brought about by resistance, unacceptable organochlorine residues in meat, and the competition that developed for the acaricide market. The competition continues and adds to the complexity of the resistance problem, and focuses attention on the need for authentic information on acaricide resistance and its significance in relation to control. This applies particularly to Africa because of the different rates at which resistance has developed in the one-host *Boophilus* ticks and the two- and three-host *Rhipicephalus* ticks, and because the recognition of resistance to a particular acaricide does not necessarily mean that resistance is widespread or that the acaricide is no longer valuable for tick control.

The resistance problem also focuses attention on the need for alternate methods of tick control that are less dependent on acaricides.

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Types of resistance

Resistance is of four basic types — arsenic, DDT, toxaphene-BHC-dieldrin and organophosphorus-carbamate (OP). They are not related biochemically, but ticks that have developed resistance to one type can subsequently develop resistance to one or more of the other types. Thus, in South Africa Whitehead (1959) described an arsenic/DDT/BHC-resistant strain of *B. decoloratus* which is also resistant to pyrethrum. In Australia, significant proportions of OP-resistant *B. microplus* have been found with resistance to arsenic, DDT and dieldrin.

There is no evidence to suggest

that resistance to arsenic, DDT or the toxaphene group can be divided into different forms. But many forms of OP resistance have been described in *B. microplus*. They have different toxicological and biochemical responses and have been given special strain names derived from the locality where they were originally collected (see table). Strains with similar characteristics have subsequently been recognized from other areas of the same country, from different countries, and even from different *Boophilus* species.

The many OP-resistant strains of *B. microplus* have caused considerable confusion. Figures 1, 2 and 3 illustrate the complex biochemical characteristics and interrelationships of the various Australian strains, their resistance factors to selected OP acaricides, and the mortality these acaricides produce when sprayed on cattle infested with the different strains. Resistance is caused by changes in the sensitivity of tick cholin-esterase (AChE) to inhibition by OP chemicals and/or by the tick's ability to detoxify the acaricide. These may be accompanied by striking changes in the amount of AChE activity demonstrable in larvae. This is illustrated by the following examples:

(*a*) Ridgelands ticks have a low level of AChE activity (21) compared with susceptible ticks (100), but the AChE is moderately insensitive to inhibition by OP acaricides.

(*b*) Biarra ticks (42) have more of a highly insensitive AChE.

(*c*) Mt. Alford detoxify chlorpyrifos in addition to having highly insensitive AChE.

(*d*) Mackay have normal AChE but detoxify coumaphos.

The resistance factors (RF) and mortality in spraying trials illustrate the progressive nature of OP resistance. Thus Ridgelands ticks have an RF of 2 to chlorpyrifos (=Dursban) which produces 99 percent mortality when sprayed on cattle; Biarra RF is 6 and mortality is 96 percent, while Mt. Alford RF is 110 and mortality is only 46 percent.

Resistance resembling Ridgelands has developed in a number of countries (see table), but it is not possible to relate other forms reported in *B. microplus* to those characterized from Australia. Some of the South American strains resemble Biarra in being resistant to coumaphos and ethion, while resistance to chlorpyrifos, which occurs in several Australian strains, has developed in Rio Grande do Sul,

OP-resistant Boophilus microplus **(Mt. Alford strain) on a Hereford from a herd which had been treated with chlorpyrifos (Dursban) every 10 to 15 days for over four months**

Geographical and chronological records of tick resistance to acaricides *

Species	Arsenic 1900-	DDT 1946-	Toxaphene-BHC-dieldrin group 1947-	Organophosphorus-carbamate group 1955-
Amblyomma hebraeum	Rhodesia 1975 South Africa 1975		South Africa 1975	South Africa 1975
Amblyomma variegatum	Zambia 1975		Tanzania 1975 Zambia 1975	
Boophilus decoloratus	Kenya 1953 Malawi 1969 Rhodesia 1963 South Africa 1938 Zambia 1975	South Africa 1954	Kenya 1964 Malawi 1975 Rhodesia 1969 South Africa 1948 Uganda 1970 Zambia 1975	Rhodesia 1975 South Africa [1] "Berlin" 1966 ="Ridgelands"
Boophilus microplus	Argentina 1936 Australia 1936 Brazil 1948 Colombia 1948 Jamaica 1948 South Africa 1976	Argentina 1953 Australia 1953 Brazil 1953 Venezuela 1966	Argentina 1953 Australia 1953 Brazil 1953 Colombia 1966 Ecuador 1966 Guadeloupe 1961 India 1964 Madagascar 1963 Malaysia 1967 Martinique 1961 Trinidad 1969 Venezuela 1966	Argentina "Goya" 1970 "Las Guerisas" 1964 Australia "Ridgelands" 1963 "Biarra" 1966 "Mackay" 1967 "Mt. Alford" 1970 "Gracemere" 1970 "Bajool" 1972 "Tully" 1972 "Ingham" 1973 Brazil "Ridgelands" 1963 "Minas Gerais" 1969 Colombia "Ridgelands" 1967 "Guaimarito" 1970 Venezuela "Ridgelands" 1967 "Guaimarito" 1970
Haemaphysalis leachii			South Africa 1976	
Hyalomma marginatum			Spain 1967	
Hyalomma sp. *(rufipes, truncatum)*	South Africa 1975		South Africa 1975	
Ixodes rubicundus	South Africa 1976			
Rhipicephalus appendiculatus	Malawi 1975 Rhodesia 1975 South Africa 1975 Zambia 1975		Kenya 1968 Rhodesia 1966 South Africa 1964 Tanzania 1971 Uganda 1968 Zambia 1975	South Africa 1975 [1]
Rhipicephalus evertsi	Kenya 1975 Rhodesia 1975 South Africa 1975 Zambia 1975		Kenya 1964 Rhodesia 1966 South Africa 1959 Tanzania 1970 Uganda 1970 Zambia 1975	South Africa 1975

* The author is grateful to the Wellcome Research Laboratories for providing the unpublished information on resistance included in this table.

[1] Additional sub-types of OP resistance have been recognized but have not been documented toxicologically or described as strains.

Brazil (Wharton and Roulston, 1976).

In South Africa, recent reports indicate that two forms of OP resistance have developed in *B. decoloratus* and *R. appendiculatus* (C.J. Howell, personal communication). The first is Ridgelands and the second is characterized by resistance to chlorfenvinphos (=Supona) and may resemble Biarra from Australia.

Confusion about OP resistance outside Australia is due to lack of published information, different methods of evaluation by various research workers, and probably to the fact that most field populations of "resistant" ticks contain both resistant and susceptible ticks. Before the resistance can be characterized, the field sample may need to be selected in the laboratory to produce a more homogeneous strain. This is illustrated in Figure 4, which shows the dosage mortality response of a sample suspected to be resistant, as compared with the responses of susceptible and "pure" Biarra strains and of the sample after culturing and selection in the laboratory. The field and F_1 populations were clearly heterogeneous; the resistance factors (calculated from the LC50 values) of 8 and 10 respectively do not represent the true potential of the resistance which proved to be Biarra with a resistance factor of 34.

Resistance is determined genetically, with DDT resistance being controlled by a recessive autosomal gene, dieldrin resistance by a dominant autosomal gene, and the various OP resistances by incompletely dominant autosomal genes (Stone, 1972). It is a pre-existing phenomenon with acaricide selection favouring the survival of mutant resistant individuals. Selection in the laboratory to "purify" a heterogeneous field sample hastens the process that would ultimately occur in the field.

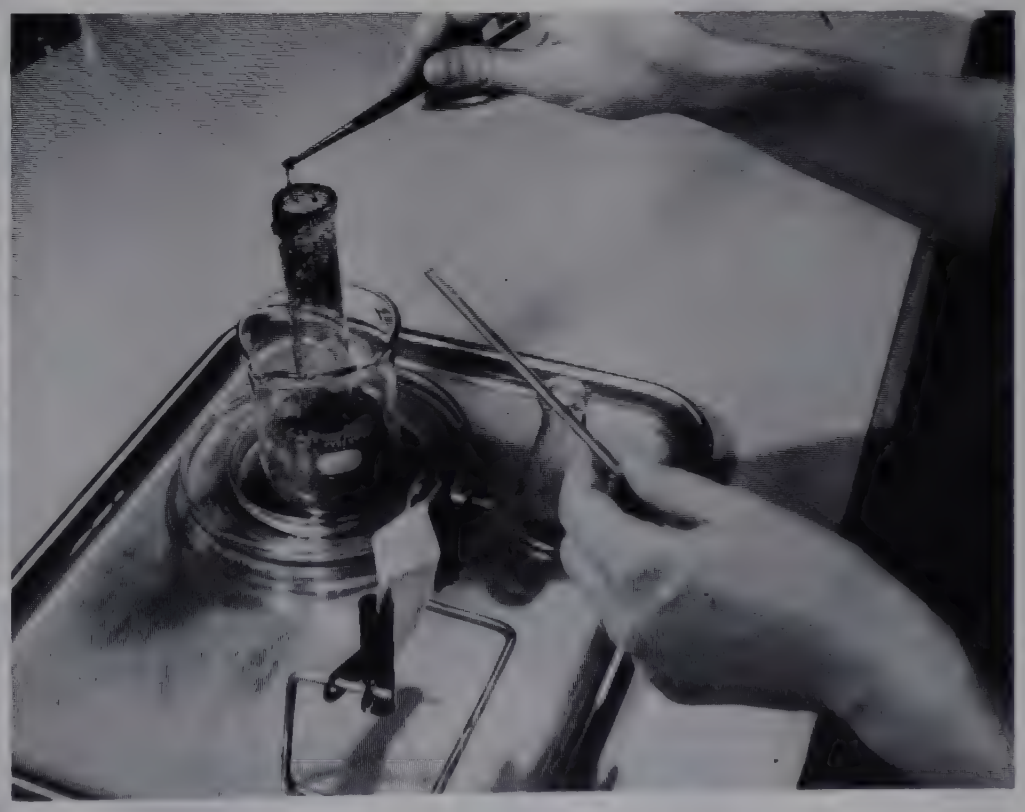
Occurrence, distribution and significance of resistance

Geographical and chronological records of resistance, from governmental or commercial sources, are biased toward countries with facilities and expertise for the recognition of resistance (see table).

The only records outside Africa, Australia and South America are on *Hyalomma marginatum* in Spain and *Boophilus microplus* in Asia. *B. microplus* has been transported to most tropical and subtropical areas from its Asian origin and has developed resistance in almost all areas where it is sufficiently abundant to warrant control measures. A notable exception is Mexico.

Also notable for a lack of resistance are *Ixodes ricinus* in Europe and the North American *Amblyomma* and *Dermacentor* ticks, for which there are no substantiated records of resistance (Wharton and Roulston, 1970). The dog tick (*Rhipicephalus sanguineus*) has developed resistance to lindane in several parts of the world, but is not important in livestock production.

The significance of resistance is not easy to quantify. Although a supply of efficient acaricides is available at reasonable cost, confusion regarding resistance and the costs involved in changing to a new acaricide are major problems. Arsenic resistance was a threat to production because no alternatives were available. But DDT and toxaphene-type resistance were relatively minor problems for *B. microplus* since OP acaricides were being developed as competitive alternatives.



The toxicological response of larval ticks may be documented by exposing larvae to different concentrations of acaricides in impregnated filter paper packets; resistance is detected when larvae survive exposure to concentrations that kill susceptible larvae

Figure 1. **Biochemical characteristics of eight OP-resistant strains of** Boophilus microplus **in Australia**

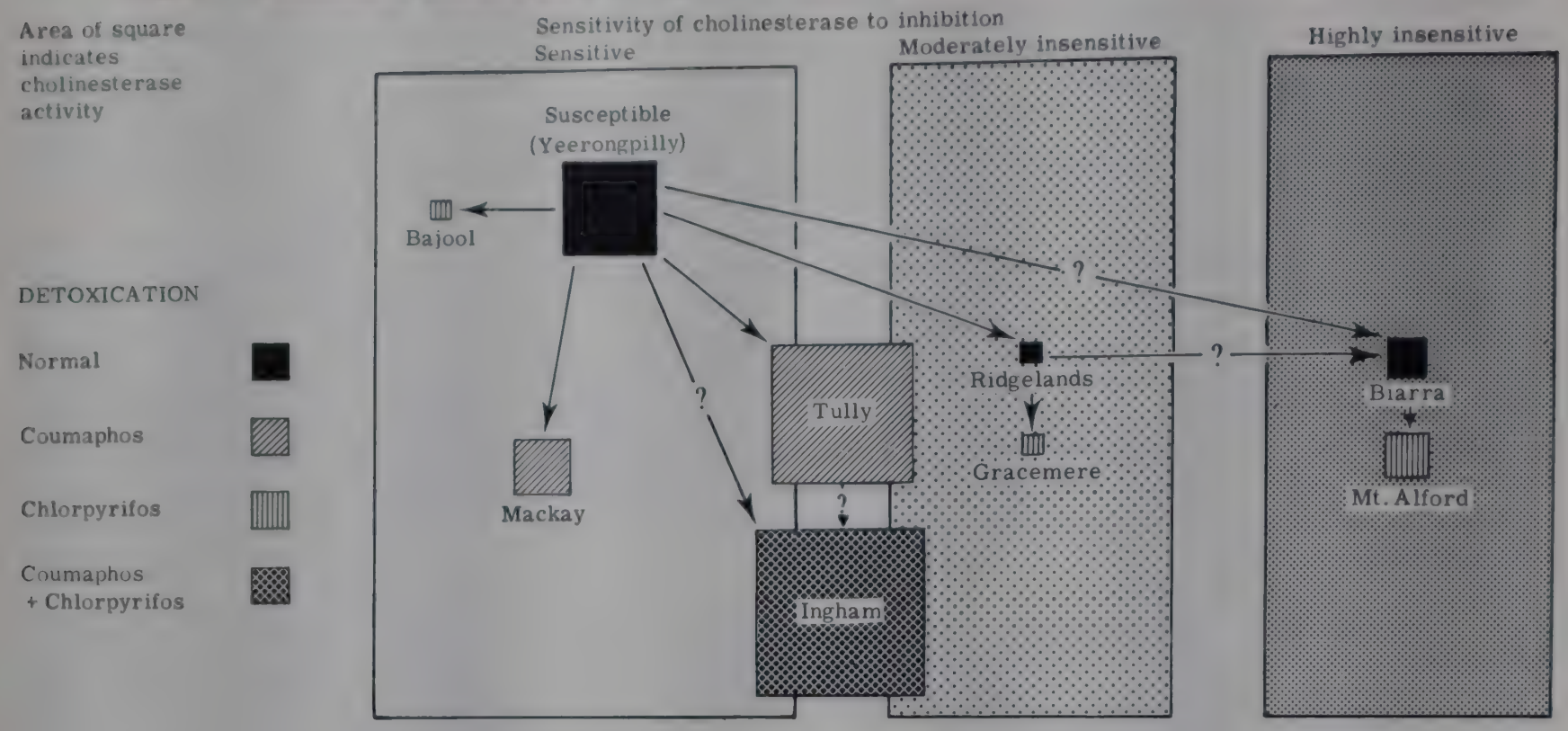
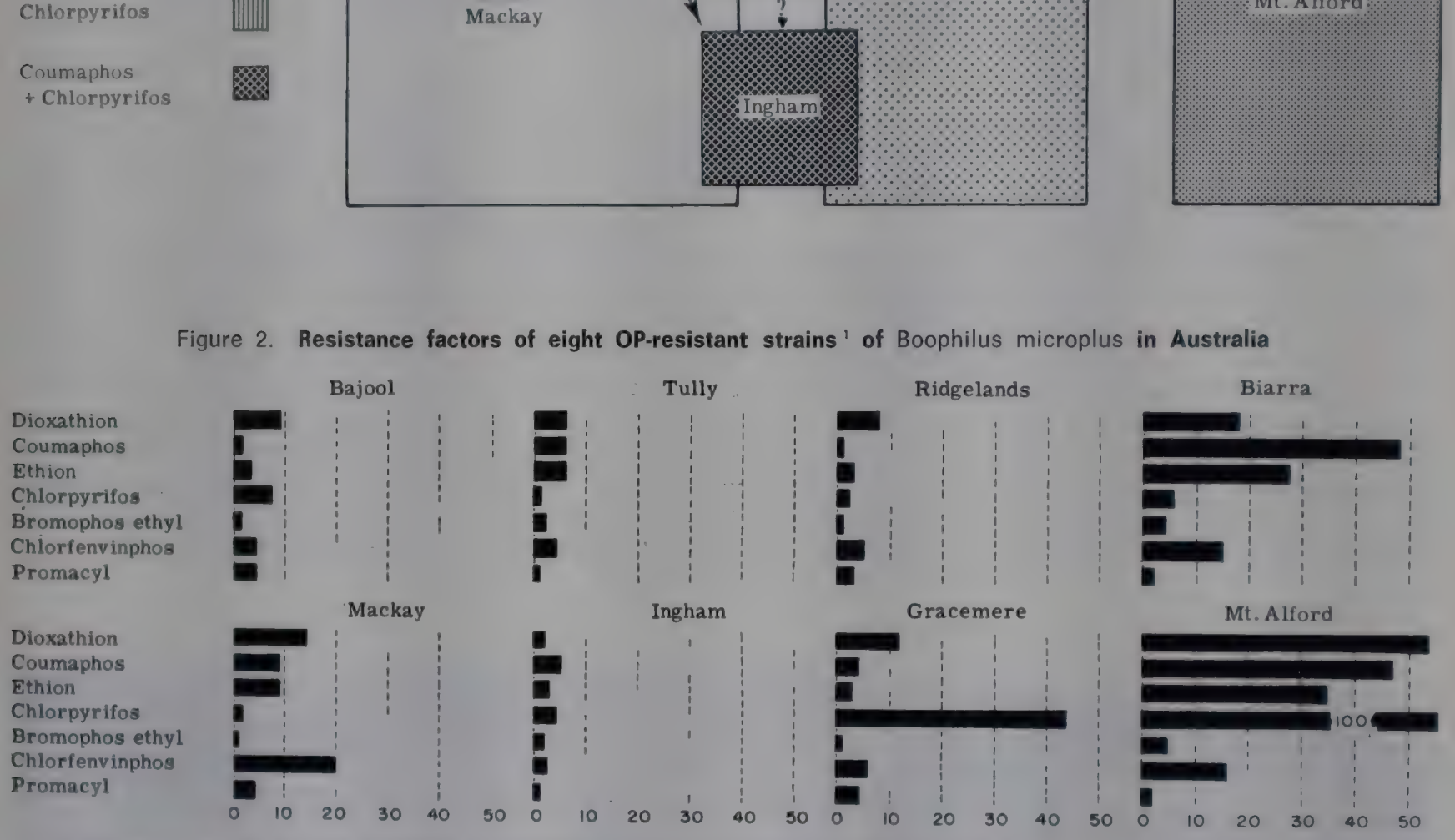


Figure 2. **Resistance factors of eight OP-resistant strains**[1] **of** Boophilus microplus **in Australia**



[1] The LC50s quoted for the field and F_1 samples are estimates since it is not logical to determine an LC50 for heterogeneous populations.

Figure 3. **Mortality in spraying trials of cattle infested with eight OP-resistant strains of** Boophilus microplus **in Australia**

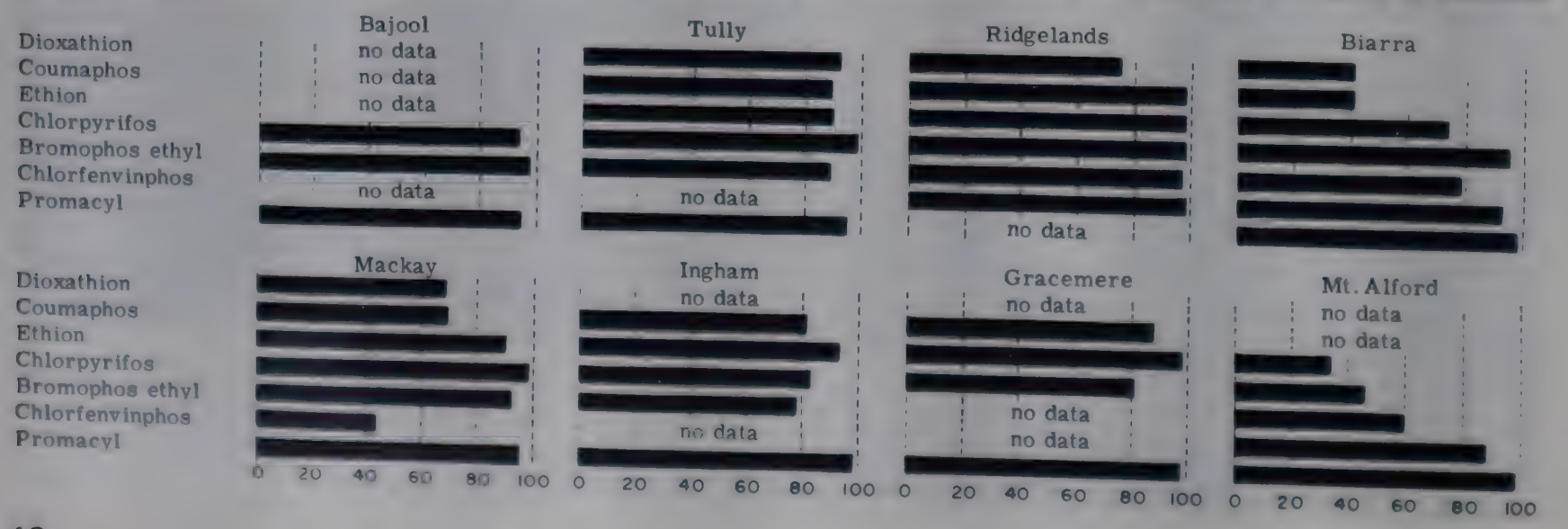
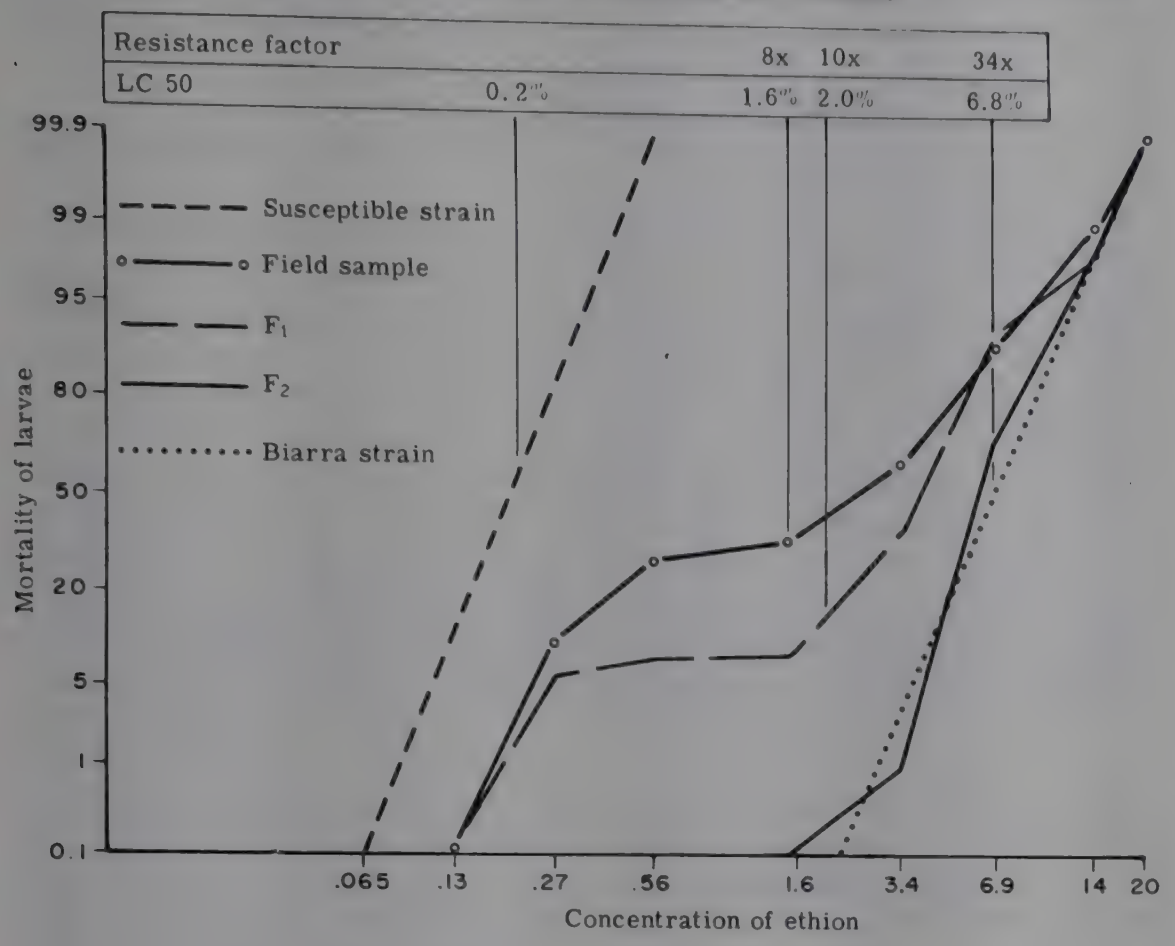


Figure 4. **Dosage mortality responses of a field strain of** Boophilus microplus **as submitted, and following selection in the laboratory, compared with responses of susceptible and Biarra OP-resistant strains**



In Australia, when organochlorines were banned for use on cattle in 1962 because of residues found in meat, several excellent and cheap OP acaricides were available. As OP resistance developed first to dioxathion, then to coumaphos and ethion, and finally to chlorpyrifos and bromophos ethyl, control problems increased. An almost frantic search for alternative acaricides has resulted in an array of new acaricides, a formamidine (chlordimeform), an iminopyrolidine (clenpyrin), a thiourea (chloromethiuron) and a carbamate (promacyl). Mt. Alford resistance in 1970 was alleviated by adding the formamidine chlordimeform to existing OP acaricides. The mixtures were effective, but chlordimeform was mainly a "stopgap" to buy time for the newer acaricides. Unfortunately, these are not as efficient as were several OP acaricides before resistance, and they cost two to three times as much (Wharton and Roulston, 1976). This excludes the recently marketed formamidine-type chemical amitraz (Taktic), which is highly effective against all strains, but has the disadvantage of being unstable unless buffered to pH 10. Since resistance is not universal and OP acaricides are still effective in many areas, the difficulties facing the cattle owner in selecting an acaricide are obvious. Where resistance has progressed to the highest level and non-OP acaricides have been used since 1970-71, there is a haunting fear that resistance to these will become evident at any time.

In South America the significance of resistance is less apparent, but the fact that amitraz and another new type of acaricide, the dithietane nimidane (Abiquito), are being marketed in Brazil (Amaral *et al.*, 1974) suggests that some cattle owners are facing control problems similar to those in Australia.

In Africa the different rates of development of resistance in *Boophilus* and *Rhipicephalus* ticks led to the use of arsenic-DDT, arsenic-BHC, toxaphene or BHC-OP mixtures, and more recently mixtures of OP-acaricides. Toxaphene and BHC have been highly effective over many years, but their future was jeopardized when resistance was observed in *R. evertsi* and *R. appendiculatus* in some localities in South Africa, and more recently in Kenya, Uganda and Tanzania. Recent reports from Africa indicate that resistance to toxaphene is widespread in countries where *R. appendiculatus* and *R. evertsi* are abundant, and has extended to *Amblyomma* and *Hyalomma* species in South Africa (see table). Toxaphene and certain OP acaricides have been banned in Kenya because of resistance. Mixtures of OP acaricides have in turn been affected, and the recent introduction of amitraz in South Africa suggests that serious control failures have occurred with these mixtures. Nevertheless, toxaphene is still used and may continue to be effective where resistance fails to develop, or where resistant individuals comprise only a small proportion of the population. In *R. appendiculatus* collected from different properties in South Africa, Baker and Shaw (1965) reported resistance factors from 2.5 to 14 in *R. appendiculatus*, indicating that they were examining heterogeneous populations (Figure 4). Control was still adequate on a property with "low" resistance but unsatisfactory on one with "high" (14×) resistance. Under these circumstances it would probably have been premature to change the acaricide on the property with "low" resistance. The finding of resistance does not necessarily mean that practical control has failed; the effective life of any acaricide should be prolonged as much as possible to conserve acaricides for the future.

In Tanzania R.J. Tatchell (personal communication) has also found "low" resistance in *R. appendiculatus*. This "low" resistance differs from the low levels of resistance illustrated in Figure 2, which may be controlled by using increased concentrations or shorter intervals between treatments. The former approach was used in Australia with chlorpyrifos to control Biarra OP resistance, and more recently with the carbamate promacyl, which controls all OP-resistant *B. microplus*, despite low levels of resistance. Increased costs are associated with this approach, but they may still be less than changing to a completely new type of acaricide.

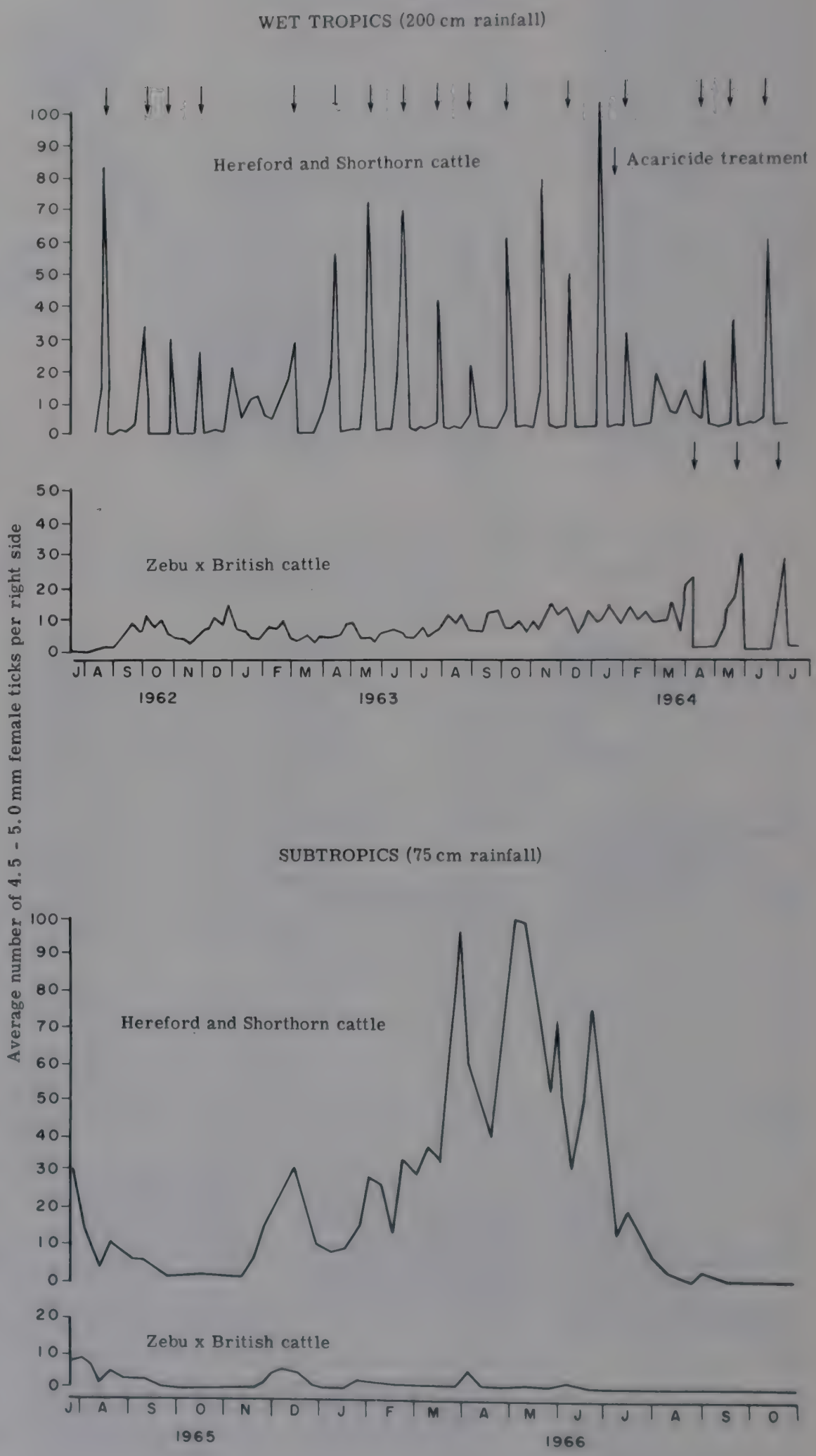
Detection, identification and characterization of resistance

Resistance is usually recognized because of failure to obtain a satisfactory kill of the parasitic stages on a treated animal. Failure is frequently due to inadequate treatment and many reports of resistance are unfounded. There is no doubt about resistance when cattle continue to be infested with large numbers of engorged ticks after frequent treatments. But the response of parasitic ticks to understrength acaricides is very similar to their response to low-level resistance or to high-level resistance in the early stages of its development. Thus field spraying tests must be conducted under standardized conditions where resistance is suspected (Baker and Shaw, 1965).

Confirmation of resistance must be made by laboratory tests. Many methods of testing the effects of acaricides have been developed, mainly by chemical companies in screening programmes. The stages most commonly used are the engorged females and the unfed larvae. The former usually provide the most useful information on potential acaricides, but unfed larvae are generally accepted as the logical stage to document resistance. Several engorged females provide sufficient larvae to test against a range of concentrations of several acaricides. The response of susceptible ticks provides the baseline when resistance is suspected. Two methods of testing have been used extensively: the Shaw method in which larvae are "dipped" for short periods in commercial formulations; and the Stone and Haydock (WHO) method in which larvae are enclosed in acaricide-impregnated filter paper packets. The latter has been recommended by FAO (1971) as a tentative method for detecting acaricide resistance.

When resistance to a new type of acaricide is found, the "resistant" population may need selection and culturing in the laboratory before its full potential and toxicological responses can be documented (Figure 4). With this information it should be possible to select discriminating doses that will kill all sus-

Figure 5. **Levels of resistance of Hereford, Shorthorn and zebu × British cattle in the wet tropics and subtropics of Australia**


WET TROPICS (200 cm rainfall)
Hereford and Shorthorn cattle
Acaricide treatment
Zebu x British cattle
Average number of 4.5 - 5.0 mm female ticks per right side
J A S O N D J F M A M J J A S O N D J F M A M J J
1962
1963
1964
SUBTROPICS (75 cm rainfall)
Hereford and Shorthorn cattle
Zebu x British cattle
J A S O N D J F M A M J J A S O
1965
1966

SOURCE: After Wharton, 1974

ceptible larvae (usually LC99 × 2); field samples are then exposed to these doses to determine whether resistance is present (FAO, 1971).

Alternate methods of tick control

When considering alternate methods of tick control, it is important to remember that the cattle industries of countries where acaricide resistance is a problem have all been dependent on acaricides to develop those industries. This does not mean that alternate methods are not available for some ticks or may not eventually be developed, but the era of highly effective acaricides has encouraged cattle owners and many scientists involved in animal production to believe that the supply will continue. Unfortunately, the adaptability of ticks limits the commercial return from acaricides and could lead to a situation in which chemical companies may find the development of acaricides not economically viable.

Approaches to insect control based on sterile males, genetic manipulations or pheromone attractants offer little promise except for attractants which could be useful for domestic pets, or for ticks with specialized attachment sites (Gladney *et al.*, 1974). Pest management systems will require detailed knowledge of the ticks' ecology and the epizootiology of the diseases they transmit. These objectives are within reach for *B. microplus* and *Babesia* (Mahoney, 1974), but not for *Anaplasma* or any other tick-borne disease association. The strategic use of acaricides to maximize their effect, the adoption of pasture rotation and alteration of the physical character of vegetation (including conservation) are well-established principles (Barnett, 1961) that have had little impact on tick control.

The most logical method of alleviating tick depredations would be to capitalize on host-parasite relationships that evolved in nature. Cattle survived in Asia and Africa despite *Babesia*, *Theileria* and their *Boophilus* and *Rhipicephalus* vectors. Host resistance, expressed by an animal's ability to prevent the maturing of large numbers of ticks, and disease immunity, are survival mechanisms for the host and for external and internal parasites. The problem is not only to utilize these attributes, but also to increase productivity. Resistance to *B. microplus* is associated primarily with zebu (*Bos indicus*) cattle. Considerable progress has been made in evolving resistant *Bos indicus* × *Bos taurus* beef and dairy cattle that limit the effects of ticks while retaining high productivity (Turner, 1975; Hayman, 1974; Mason, 1974). Similar approaches may ultimately benefit the more complex and demanding African environment. In this context the domestication and harvesting of game have obvious merit (King and Heath, 1975).

Utilization of host resistance, while offering an attractive approach to tick control, raises many questions even with the relatively simple *B. microplus-Babesia* association (Figure 5). Resistance is an acquired characteristic and each animal develops its own level of resistance in response to tick challenge; the level may be high (as in most zebu cattle) or low (as in most European cattle), but a wide range of resistance occurs in all breeds of cattle. It is heritable, and selection and breeding for tick resistance are possible not only in zebu × European breeds, but also within European breeds. However, selection for resistance or culling for susceptibility must at present be based on tick numbers surviving on cattle exposed either naturally or artificially to tick challenge. This raises obvious problems for the cattle producer who is concerned about the effects of these ticks on production. Markers for tick resistance are being sought, but intensive studies on the cattle-tick relationship highlight its complexity and the difficulties of either finding a simple marker for resistance or enhancing the low resistance exhibited by European breeds of cattle. Nevertheless, the prejudices against zebu cattle in Australia are dying, and recognition of their virtues and potential in crossbreeding programmes indicates a more rational and hopeful prospect for using this approach to improved tick control with less dependence on acaricides.

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Recent developments in classical swine

Swine fever is a contagious disease of both domestic and wild pigs which brings about septicaemia with haemorrhagic lesions. In the acute form, morbidity may be as high as 100 percent, and mortality almost as high. The causative agent is a small RNA virus. The disease is widespread in nearly every continent where pig raising has been developed. Like foot-and-mouth disease, swine fever is a major enzootic disease which causes enormous economic losses because of its extremely contagious nature. Therefore, all infected pigs and those that have been in contact with them should be promptly slaughtered. Research over the last 10 years has led to the development of a particularly sensitive method of diagnosis which involves the use of fluorescent antibody techniques. As a result, incidence of the disease has become increasingly low. However, the "asymptomatic" or subclinical forms of infection still occur and are difficult to detect. At present the only available measures against this disease are quick and accurate diagnosis of slaughtered, sick and infected animals, and vaccination. In the short run and for economic reasons, prophylaxis based on vaccination remains the best control procedure pending total eradication.

This article will summarize what is known about immunizing pigs against swine fever. The symptoms and course of the infection, the principal characteristics of its epizootiology, some recent information on the virus, and the problem of serological variants will be reviewed. Particular attention will be given to vaccination procedures and the different types of vaccines that have been used (inactivated and live virus vaccines), with emphasis placed on the advantages and disadvantages of the vaccines in respect of safety, effectiveness, control and utilization.

Symptoms and course of the infection

The animal is infected mainly through the mouth and nose. In the acute form, following a brief incubation period of two to three days, the first symptoms are high fever, loss of appetite and a profound prostration followed quickly by nervous, respiratory and digestive disorders. Death usually occurs within seven to 12 days. Signs of severe septicaemia and congestive and haemorrhagic lesions are found on the skin and in the mucous membrane, spleen, ganglia and kidneys. Secondary bacterial infections cause digestive disorders (enteritis) and respiratory diseases (pneumonia) in the subacute forms. Histologically, the composition of the blood is greatly altered by a severe leucopenia due to a considerable decrease in the number of polymorphonuclear neutrophils. Viremia occurs 24 hours after infection and continues until the animal dies. The nasal and ocular discharges and urine contain the virus and are highly infectious.

The severity of clinical and pathological lesions and the incidence of mortality vary with the virulence of the virus strain causing the disease in a given area. In many countries swine fever recurs in an unaccustomed form that is difficult to identify (Aynaud *et al.*, 1972). Because of its attenuated character, this form of the disease has been termed subclinical or "chronic" infection. Observed disorders are most often associated with reproduction (sterility, abortions, stillbirths), neonatal mortality and delayed growth. Adult sows may show no clinical symptoms but could be dangerous carriers of the virus. In herds infected with chronic swine fever virus the general level of reproduction is seriously lowered: fertility and prolificity drop sharply. Mortality is generally low (1 to 10 percent), depending on the virulence of the strain. This subclinical form of infection is especially serious because in the long run it reduces production considerably and thereby causes the inevitable failure of the enterprise.

Epizootiology

The infectious virus in the saliva, nasal and eye discharges and urine spreads far and wide outside the host

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fever vaccination

by J.M. Aynaud and G. Corthier

animals. The virus is resistant to heat, desiccation and changes in pH, and may remain infectious outside the host for a long time. In the acute forms the virus usually enters the host through the nose or mouth, and is easy to diagnose and eliminate. In the subclinical forms it is transmitted by the pregnant sow, and only the embryo, foetus and young piglets show clinical manifestations of the disease in its subclinical form. Because of the nature of pig breeding (a rapid turnover of generations resulting in a high proportion of young and susceptible individuals, and the herding of animals in small areas), large herds of unvaccinated sows offer an environment particularly favourable to the development and propagation of these attenuated strains of swine fever virus, which are often difficult to diagnose. The disease thus tends not only to persist, but even to spread and extend to many herds when animals are bought and sold.

Table 1. **Genetic markers of swine fever virus in relation to its pathogenicity to pigs**

Virus strain	Growth in cell culture	Heat stability of the virus (56°C)
Wild strains fully virulent to pigs	Optimum growth of hot strains at high temperature (39-40°C)	Solid strains resistant at 56°C for 30 min.
Strains attenuated for pigs (live virus vaccine with no residual pathogenicity)	Optimum growth of cold strains at low temperature (33-34°C)	Fragile strains inactivated at 56°C in 30 min.

SOURCE: Aynaud, 1972.

Table 2. **Comparison of properties of inactivated and live vaccines**

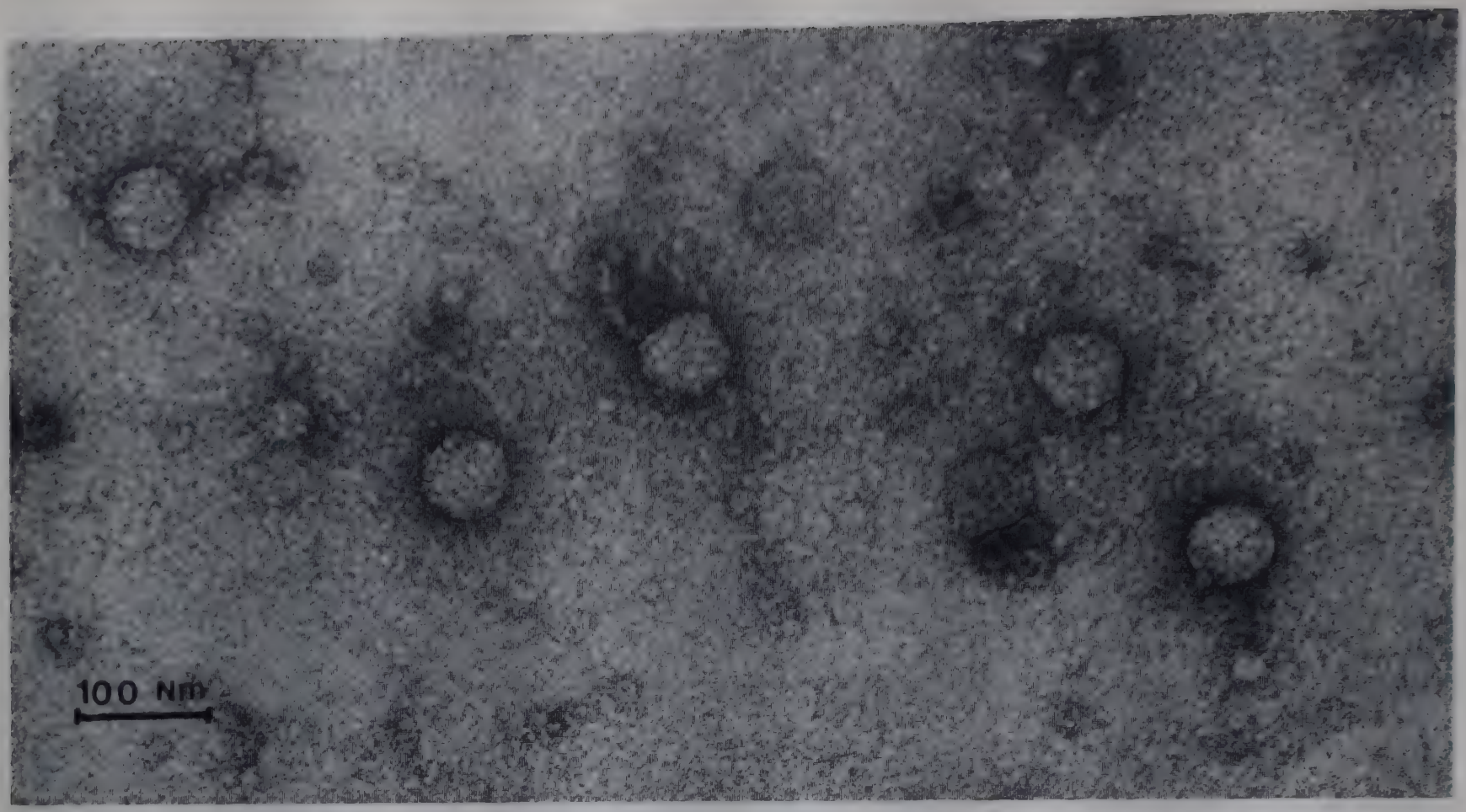
Vaccine	Safety for pregnant sows and young piglets	Effectiveness of immunity	Booster injection
Inactivated virus (formol, crystal violet)	Excellent	Late, weak, lasting a few months	Necessary
Live virus with residual pathogenicity	Mediocre	Early, intense, lasting several years	Unnecessary
Live virus with no residual pathogenicity	Excellent	Early, intense, lasting several years	Unnecessary

Animal health measures and regular immunization with live virus vaccine are, in the short run, the only effective way to check the spread of the virus in the pig population.

Properties of the virus

The agent of classical swine fever is a small enveloped RNA virus belonging to the "togavirus" group. Though quickly destroyed by lipid solvents and detergents, it is highly resistant to heat, desiccation and changes in pH. The extremely contagious nature of the disease is due to the persistence of the virus outside the cell and outside the host. Only one antigenic type is known, within which at least two subgroups of serological variants were recently brought to light by the seroneutralization technique (Corthier *et al.*, 1974). The first and most important subgroup is made up of many virulent strains and most of the attenuated strains used as live virus vaccine. The second subgroup includes attenuated strains (American strain 331) causing the subclinical or chronic forms of the disease. However, the antigenic uniqueness of the virus is well demonstrated by the broad antigenic overlapping observed among all the strains studied. The cross-immunity tests performed with various live virus vaccines have always demonstrated the antigenic uniqueness of the virus.

Finally, Corthier *et al.* (1974) have established that the bovine viral diarrhoea (mucosal disease) virus is



Morphology of the Alfort swine fever virus strain. Negative staining (uranyl acetate) of purified viral suspension. (From unpublished study by H. Laude)

dominant over that of swine fever. This suggests that the virus of bovine viral diarrhoea derives phylogenetically from that of swine fever, and not vice versa. If this is so, the bovine viral diarrhoea virus may be regarded as a particular serologically variant strain of the swine fever virus, attenuated for pigs and well adapted to cattle and sheep.

The pathogenicity of the swine fever virus is connected to a number of *in vitro* characteristics or genetic markers (Aynaud *et al.*, 1972). Strains that prove highly virulent in cell culture are described as hot and solid, and those that show attenuation as cold and fragile.

Rapid multiplication of the virus in cell cultures, a maximum virus production at around 40°C, and stability at 56°C are characteristics of virulent strains that kill pigs in eight to 12 days. Conversely, slow multiplication in cell cultures, maximum virus yield at 33 to 34°C, and fragility at 56°C characterize strains devoid of virulence and hence usable as vaccine (Table 1). Knowledge of these *in vitro* genetic markers in relation to pathogenicity is valuable for epidemiological purposes on the one hand, and for the development and testing of virus strains usable as live vaccine on the other.

Properties of vaccines

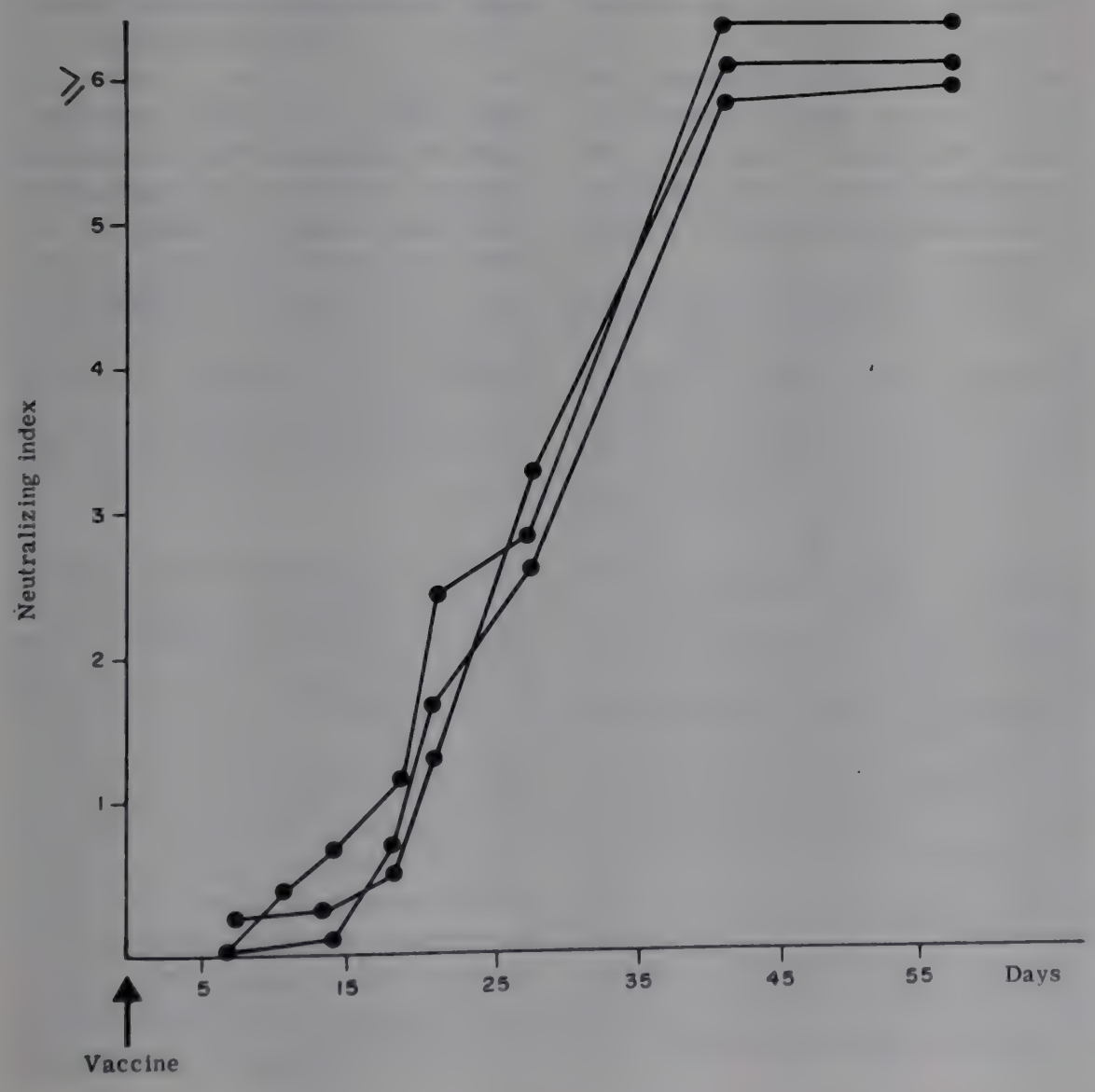
In view of the advances recently made in immunology, particularly in the relationship between resistance to infection and local immunity response, it is necessary to emphasize the qualities required for any modern vaccine against swine fever: the inoculum must be totally safe for pregnant sows and young piglets, and the immunological response induced by a single injection of vaccine must be quick, intense and long-lasting. This can be measured by resistance to challenge with virulent virus and by the kinetics of the appearance of neutralizing antibodies in serum. Thus a good swine fever vaccine must be able to induce solid immunity quickly enough to prevent infection and the appearance of clinical symptoms. Actually, virus carriers are clinically healthy, but harbour the virus and are consequently susceptible to infection. This condition is often favoured by the weak immunity induced by insufficiently effective vaccines such as those of killed virus.

Inactivated vaccines. Killed virus vaccines are usually prepared from tissues and blood of pigs infected with a virulent strain. When administered subcutaneously, the safety is excellent, but unfortunately the immunity response is usually mediocre (Van Bekkum, 1966). As shown in Table 2, immunity response is slow and weak, and lasts only a few months, even after several booster injections (Corthier and Galicher, 1975). Vaccinated animals may exhibit good clinical resistance to challenge infection, but it is not certain that the induced immunity protects them effectively against invasion by the virus and its persistence in the host. It is known that when sows vaccinated with inactivated vaccine are challenged during gestation with a fully virulent strain, they withstand

the disease well. When they farrow, however, the virulent virus is found regularly in the foetuses, and disorders and malformations are observed in new-born piglets (Huck and Aston, 1964). These are epidemiologically important observations which indicate that the vaccinated sow, though resistant to the disease, is still susceptible to the virus, and that the virus penetrates and multiplies in the maternal tissues and infects the embryo or foetus (Stewart *et al.*, 1972). It may therefore be asserted that the use of killed virus vaccines in a country where swine fever is still active can create conditions favourable to the development of virus carriers. For these reasons inactivated vaccines are now seldom used.

Live virus vaccines. After the work by Koprowski in 1946 on the adaptation of the virus to rabbits, a large number of attenuated strains were successfully proposed for use as live virus vaccine (Olah and Palatka, 1967; Sasahara *et al.*, 1969). By numerous serial passages through rabbits or in cell cultures, these strains lost all or part of their pathogenicity to pigs while retaining their multiplying and immunogenic properties. Finally, knowledge about the relationship between the genetic markers of the virus and its pathogenicity (Aynaud *et al.*, 1972) made possible a more rational and effective approach (Launais *et al.*, 1972).

Figure 1. **Development of neutralizing antibodies in serum of piglets inoculated with the Thiverval strain of swine fever virus**



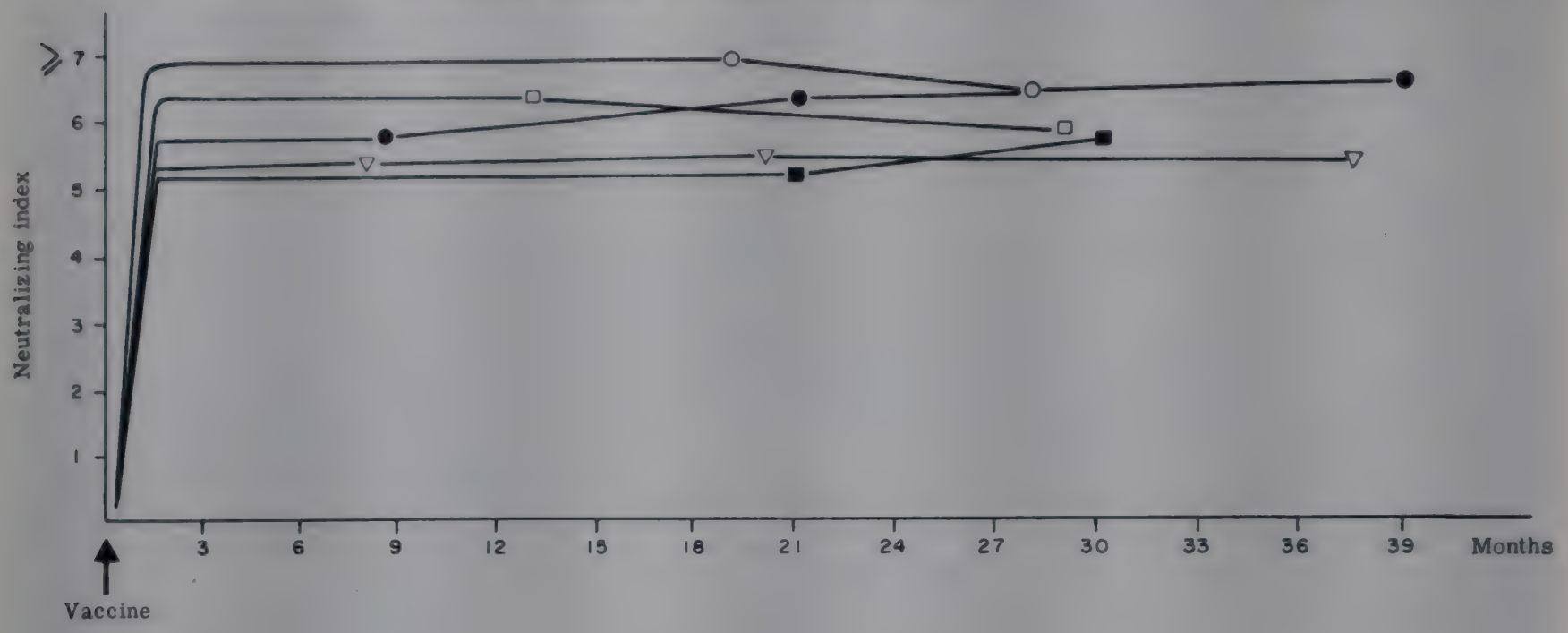
Live virus vaccines

Safety. Vaccines can be classified into two broad categories in terms of their safety for pigs: those with residual pathogenicity, and those without it.

1. *Strains with residual pathogenicity.* The residual virulence of these strains is revealed mainly in young piglets which show signs of infection, and in gestating sows which show reproductive disorders. After a few serial passages through susceptible piglets, these strains can recover their virulence. Their low degree of safety is associated with insufficient attenuation and the genetic instability of their acquired characteristics owing to the heterogenicity of the constituent virus population. The reason for this genetic heterogenicity is that these strains were not cloned when passed through rabbits or tissue cultures. Furthermore, nothing is known about their genetic markers. They are rightly suspected of being responsible for the development of the asymptomatic and chronic forms of swine fever that are increasingly observed in the field (Dunne and Clark, 1968). Because of these serious disadvantages, these strains are being used less and less.

2. *Strains with no residual pathogenicity.* Inoculated into gestating sows and young piglets (Olah and Palatka, 1967), these recently developed strains (the Chinese, GPE^- and Thiverval strains) have proved harmless to the embryo and foetus. Viremia is detectable either slightly or not at all. The excellent safety of these new strains is probably due to satisfactory attenuation of the viruses and the good genetic stability of their immunogenicity (Sasahara *et al.*, 1969; Launais *et al.*, 1974). These strains, unlike those in the previous category, are genetically homogeneous because they are obtained through long selection from many serial clonings in cell cultures at low temperature (the GPE^- and Thiverval strains). Besides, their genetic markers have been clearly established. They are genetically stable, the risk of reversion to virulence being very slight because of the existence of two apparently independent mutations, one cold and the other fragile, and also because the vaccine is produced at low temperature (30°C) (Launais *et al.*, 1972). These strains retain their attenuated properties even after several serial passages through susceptible piglets, which demonstrates the genetic stability of their

Figure 2. **Persistence of neutralizing antibodies in serum of five sows after vaccination with the Thiverval strain**



safety. The excellent results obtained following their large-scale use in the field both in Japan (the GPE⁻ strain) and in Europe (the Chinese and Thiverval strains) confirm their high degree of safety.

Thus the problem is not in the principle of vaccination with live virus, but mainly in the choice of vaccine strains and in the techniques used for vaccine preparation. It is unfortunate that the bad example of accidents with the strains of the first category of swine fever virus has put live virus vaccination under a cloud and thus inhibited wide use of the strains in the second category.

Effectiveness. Whether they belong to the first category or the second, all live virus vaccines developed and used so far have in common a property that is of particular interest to stockmen and veterinarians — their excellent immunogenicity. The immunity response following a single injection of vaccine, whether measured by the resistance to virulent challenge or by the neutralizing antibodies, is quick, intense and long-lasting.

From the fifth day following vaccination, animals become resistant to challenge infection, and neutralizing antibodies are detectable from the seventh to tenth days (Figure 1). The neutralizing activity of the serum reaches its peak at the end of a month and maintains the same level throughout the economic life of the animal (more than three years in breeding animals vaccinated with the Thiverval strain, according to an unpublished study by Aynaud) (Figure 2). There is a close relationship between the presence of neutralizing antibodies in the serum and protection against challenge infection, but not the reverse. In these conditions, booster vaccination turns out to be unnecessary because of the duration of the immunity conferred by a single injection.

Maternal immunity is transmitted passively to the newborn piglet in the colostrum, which is rich in immunoglobulins possessing neutralizing activity. This passive immunity in the blood of the piglet slowly decreases with time (half-life of about 14 days) and affords effective protection against virulent infection for 40 to 60 days. Thus the immunity induced by the live virus vaccines is very strong: not only do animals resist the disease well in the clinical sense, but they are also protected against infection, i.e. against the multiplication of the virulent virus in the host. In sows vaccinated with attenuated strains and challenged during gestation with the virulent virus, the embryo or foetus is never infected by the virus because the intense maternal immunity effectively blocks the entry of the virus and its multiplication in the tissues of the sow, and prevents its passage through the placenta (Stewart *et al.*, 1972).

Testing. Testing for effectiveness poses no special problems because tests for protection against challenge infection are simple and easy to perform. However, tests for safety are more difficult and their procedures have often changed with the passage of time. Because of the particularly high susceptibility of embryos and foetuses to the swine fever virus, the lack of disturbance or change in breeding performance (fertility and prolificity) in pregnant sows is now viewed as the most sensitive way of testing the safety of swine fever vaccines.

Use. Immunocompetence develops in pigs from the sixtieth day of foetal life. Thus vaccination can be carried out from the earliest weeks of life in piglets born of non-immune sows. But in piglets born of immunized sows, the presence of the passive immunity transmitted through the colostrum does not allow vaccination until 35 to 50 days after birth, according to the level of colostral antibodies in the serum; if done earlier, the vaccination will be entirely ineffective. The vaccine is traditionally

administered intramuscularly; this procedure is simple, effective and yields excellent results. The intranasal route gives comparable results, but owing to losses due to dispersal of the material, 10 to 100 times more vaccinal virus must be used.

Conclusions

Should one vaccinate? If so, under what conditions? An attempt to answer these questions should take into account factors such as the epizootic situation, number of animals involved, and categories of animals.

1. If swine fever is rare in a given country or region, vaccination is not obligatory. However, the diagnostic laboratory must remain watchful and conduct regular serological surveys and checks, particularly among breeding animals, to make sure that the pig population exhibiting no positive serological reactions is really free of swine fever.

2. If swine fever is prevalent, vaccination must be carried out under the following conditions:

As the disease is so prevalent that the laboratory has difficulty in diagnosing the subclinical form of infection in breeding animals, health measures, particularly a "stamping out" policy, will prove both expensive and ineffectual. They eliminate only the few foci of infection identified by the laboratory, while unidentified ones persist and tend to spread. For both economic and scientific reasons, live virus vaccines with no residual pathogenicity must be used. Stockmen should be able to rely on vaccination because in the short run it is the only method they can easily afford which can prevent the disease and thus avoid heavy economic losses. Regular vaccination providing the pig population with a protective umbrella of immunity effectively checks the invasion of herds by pathogenic viruses of low virulence introduced through the purchase and sale of animals. Vaccination is found to be followed by a decline in the frequency of breeding disturbances in large suspected herds in which the presence of a mildly virulent virus has been detected by serological tests (Aynaud, [unpublished]).

The size of the herd is an important parameter because the appearance of a focus of swine fever infection in a herd of several hundred, or even several thousand, inflicts enormous losses compared with those caused by a focus of infection in a small family-type operation.

Because of the length of the economic life of a sow, her frequent role as a virus carrier and the passive protection provided for 40 to 60 days in piglets following ingestion of immune colostrum, breeding animals should be the first to be vaccinated regularly.

Protection of breeding animals in a pig population by immunization with the live virus vaccine offers the following advantages:

- Low cost of administration because it is administered to 10 to 15 percent of the total pig population, and only once in the economic life of the sow.

- Solid and lasting immunity from a single vaccination.

- Elimination of virus carriers and reduction of losses from reproductive disorders caused by chronic or subclinical swine fever.

- Passive protection by the colostrum of piglets intended for fattening for 40 to 60 days, or one fourth to one third of their economic life.

Effective and harmless, the recently developed Chinese, GPE^- and Thiverval strains of live virus vaccines are being increasingly and successfully used in the field. Their use will reduce economic losses due to swine fever and in the short run will restore the normal productivity of sows in herds in which mildly virulent strains responsible for asymptomatic or subclinical forms of the disease insidiously spread. At a more practical level, new cell culture vaccines (the GPE^- and Thiverval strains) are relatively easy and inexpensive to produce and titrate.

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Using waste bananas

by J. Le Dividich, F. Geoffroy, I. Canope and M. Chenost

As world demand for milk and meat increases, competition in the use of crops for human food and for animal feeding is becoming more intense. World grain production, for example, has declined in recent years, and in consequence stocks have been depleted and prices have risen to such a high level that it is becoming uneconomic to continue feeding grain to livestock as generously as in the past. Thus there is more reason now than ever before, particularly in the tropical regions where animal protein for human consumption is scarce, to make use of every crop or by-product that could serve as animal feed.

While direct feeding of sugarcane to cattle is now well established (Leng and Preston, 1976), the feeding of bananas, another important tropical crop in terms of volume and energy value, has been relatively neglected. This is largely because bananas are principally a human food, but is also partly attributable to the fact that their value as animal feed has not been adequately considered (Chenost *et al.*, 1969; FAO, 1969).

It is relevant to note in this context that according to the Institut français de recherches fruitières d'Outre-Mer (IFAC), for every ton of bananas packed and exported to the fruit markets of the world, about 750 kg are rejected as being either unsuitable or in excess of requirements. This discarded fruit represents 10 to 20 percent of the total crop, the variation depending on how culling is done during packing (which depends on the market), and the amount of fruit that is rendered unusable by fortuitous circumstances such as gales and hurricanes.

Of the 36 million-ton world banana production (FAO, 1975), it may be estimated that 7 to 10 million tons per year (20 to 30 percent) could be recovered as animal feed. But of this, a substantial quantity is either used in a haphazard way or lost to the animal industry.

The purpose of this article is to review what is currently known about the use of waste bananas as animal feed and to consider areas of study warranting further attention.

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Composition and ensiling properties

The composition of all banana varieties harvested is determined chiefly by degree of ripeness. Table 1 shows the composition of the green and ripe fruit.

Bananas have a high water content (78 to 80 percent). In the green state in which they are generally picked and packed, the dry matter consists mainly of starch (72 percent), which on ripening changes into simple sugars (saccharose, glucose and fructose). The cellulose content is low (3 to 4 percent) and most of it is found in the skin. The inorganic fraction is poor in the more important minerals, Ca and P, but is rich in potassium.

Whether green or ripe, the banana has a low protein content (N × 6.25) and is deficient in lysine and in sulphur-containing amino acids (2.3-2.9 g/16 g N). Moreover, the banana contains tannins which are only slightly polymerized in the green fruit and which therefore inhibit the action of enzymes. In the ripe fruit, however, there is higher polymerization.

Because of its high fermentable sugar content, the banana is easy to ensile. On the basis of work done recently in Guadeloupe (Sève *et al.*, 1972; Le Dividich and Geoffroy, 1973; and Le Dividich *et al.*, 1976) it may be concluded that the ensiling of bananas can be successfully undertaken if the normal rules of silage making are observed, ensuring adequate compaction and drainage; no additives are required. Ripe bananas compact easily, but bananas to be ensiled green should be chopped. Alternatively, green bananas may be ripened either naturally or artificially in an acetylene atmosphere (a proce-

as animal feed

dure developed by IFAC at its Guadeloupe Station) prior to ensiling. In silage made from green bananas the starch keeps well (with losses of only 6 to 7 percent), whereas 84 percent of the simple sugars of the ripe bananas are either degraded or disappear. As a result, weight losses (Table 1) are almost three times less for green banana silage (10 to 15 percent) than for silage from ripe bananas (30 to 35 percent).

The silage stabilizes in three to four days and keeps for at least six months. The characteristics of silage from ripe fruit (e.g. pH and lactic acid content) may be more favourable than those of silage from green bananas. But on balance green banana silage is to be preferred, particularly when sudden peaks occur in banana supplies owing to seasonal factors, market constraints and meteorological conditions.

Use in pig feeding

Fresh bananas. The digestible energy (DE) value of the green banana (Table 2), measured with pigs of 40 kg average weight, is 3 181 kcal/kg of dry matter (i.e. 80 to 86 percent that of maize). This value may be improved by:

(*a*) cooking, which considerably increases the efficiency *in vitro* of

Alpine goats eating fresh green chopped bananas

Table 1. **Composition of banana export rejects at different stages of maturity and preservation**

	Green, 3 to 5 days after picking	Ensiled green	Ripe	Ensiled ripe
Physical composition	..... *Percentage of dry matter*			
Banana peelings	20		18	
Banana pulp	80		82	
Chemical composition	..... *Percent*			
Dry matter content in fresh feed	21.2	29.0	21.7	23.5
Crude fibre [1]	3.7	5.3	3.8	6.1
Crude protein [1]	6.4	3.8	5.3	8.1
Sugars soluble in alcohol at 80° G.L. [1]	1.8	0	73.6	17.3
Starch [1]	72.3	70.9	3.4	6.8
Ash [1]	4.6	3.8	5.2	5.7
pH		4.2		3.8
Lactic acid (g/% DM)		5.3		10.1
Volatile acidity (g CH_3 COOH/100 g DM)		1.8		3.0
Ethanol		0.2		2.3
Losses as percentage of ensiled dry matter		13.5		33.9

SOURCE: Le Dividich, Sève and Geoffroy, 1976.
[1] On dry matter basis.

Table 2. **Apparent digestibility and digestible energy content of fresh bananas for pigs**

	Green raw	Whole cooked	Whole green, peeled	Whole ripe
Digestibility coefficient	..... *Percent*			
Dry matter	[a]83.5	[b]87.9	[b]88.6	[b]89.5
Organic matter	[a]84.2	[b]88.6	[b]89.1	[b]90.1
Energy	[a]79.5	[b]84.3	[b]85.5	[b]85.5
Nitrogen	[a]−19.0	[b]26.4	[a]−1.6	[b]38.4
Digestible energy	..... *Kcal*			
Per kg dry matter	3 181	3 439	3 440	3 327
Per kg fresh weight	674	743	1 021	722

SOURCE: Le Dividich and Canope, 1975
NOTE: Averages with the same index letter are not significantly different $P < 0.05$.

amylase in starch digestion (Beroard-Cerning and Le Dividich, 1976);
(*b*) peeling, which causes an 8 percent improvement in DE, but is of little practical value because the improvement obtained is offset by a 20 percent loss of dry matter;
(*c*) ripening the fruit (Table 2).

Adding bananas to a pig ration reduces the digestibility of the total nitrogen content of the ration (Le Dividich and Canope, 1970). This means that the digestibility of the protein in bananas (Table 2) is either negative (as in green bananas) or very low (as in ripe bananas).

Thus for pigs fresh bananas are a bulky feed of low energy value (about 700 kcal DE/kg, or 20 percent of the energy value of maize). They also depress the utilization of the nitrogen in the ration. When including them in pig diets it is therefore necessary to provide both energy and nitrogen supplementation.

Fresh green bananas may be fed chopped into thin slices or crushed, and when ripe may be offered whole. Some authors (Viteri *et al.*, 1970; Le Dividich, [unpublished] and Shillingford, 1971) have found little influence of the banana's degree of ripeness on animal growth performance, while others stress the value of the less astringent ripe banana, which is more easily digested than the green fruit and contributes to better growth. Cooking the green fruit improves the growth rate of pigs by 10 percent and improves the nutritional efficiency of diets, but is limited by cost.

In Guadeloupe studies on growing pigs (27 to 54 kg live weight) raised in cages and fed four diets based on bananas and soybean cake, with protein contents ranging from 12.5 to 20.9 percent, gave the following results (Le Dividich and Canope, 1975):

- Increased protein content significantly improved growth performance and feed conversion efficiency.

- Daily net nitrogen retention rose significantly ($P<0.01$) to a level corresponding to a 17.8 percent protein content in the diet; this resulted in the recommendation that for growing

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Table 3. **Effect of level of concentrates in banana-based rations on the growth performance of pigs (25 to 95 kg live weight)**

		Lot		
		1	2	3
Daily feed intake				
Concentrate for pigs weighing 28 to 60 kg				
Amount fed	*kg*	0.9	1.2	1.5
Digestible energy	*kcal*	2 952	3 996	4 995
Crude protein	*g*	268	271	269
Concentrate for pigs weighing 60 to 95 kg				
Amount fed	*kg*	1.1	1.4	1.7
Digestible energy	*kcal*	3 646	4 690	5 689
Crude protein	*g*	341	344	342
Bananas		. . . . . *Kg*		
Fresh weight		[a]4.63	[b]4.13	[b]3.49
Dry matter		[a]0.99	[b]0.89	[c]0.75
Total dry matter intake		[a]1.90	[b]2.04	[c]2.16
Growth performance				
Average daily weight gain	*g*	[a]515	[b]589	[c]624
Feed conversion ratio (kg dry matter/kg weight gain)		[a]3.70	[a]3.63	[b]3.47
Carcass yield				
Dressing percentage		[a]70.2	[a]71.3	[b]72.9
Weight of digestive tract, full	*kg*	[a]11.4	[ab]10.2	[b]9.5
Average backfat thickness	*mm*	[a]23.0	[a]24.8	[b]28.3

SOURCE: Le Dividich and Canope [unpublished data].
NOTE: Averages with the same index letter are not significantly different $P < 0.05$.

pigs, the diets should contain 18 percent crude protein. Because of the quantities of banana ingested, a daily supplement of 270 g protein is necessary. This is in accord with the results of Galles, Clavijo and Maner (1969) and Oliva, Gelleri and Maner (1970) for green and ripe bananas.

Adding fresh bananas (which are high in water content and low in energy) to pig diets results in an energy deficit in the ration that may be overcome in three ways:

1. By dehydration to increase energy concentration. This would make it possible to add 50 to 75 percent green banana flour to the ration (Oliva, Gelleri and Maner, 1970); however, the cost per kg of weight gain would increase because of the cost of dehydration.

2. By raising the intake of fresh bananas through *ad libitum* feeding. Le Dividich and Canope (1975) showed that under *ad libitum* feeding (with two feedings per day), a pig can increase its intake by 20 to 30 percent. However, carcass yield is lowered because of the enlarged digestive tract, and this limits the commercial advantage of a large intake of bananas.

3. By providing more feed supplements (Table 3). The supplementation would result in a linear increase in growth rate, an improvement in the feed conversion ratio and a higher carcass yield, but the level of fat in the carcass would be high.

In practice, the choice of feeding systems or level of supplementation is determined by economic considerations, i.e. the price of the feed supplement in relation to the added value of the carcass.

Ensiled and dehydrated bananas. The work done in Guadeloupe shows that banana silage is highly acceptable to the growing and fattening pig (Table 4). Despite its depressing effect on the digestibility of the ration protein, green banana silage has nearly the same food value as the ripe fruit. On the other hand, ripe banana silage makes for poor growth performance because of its higher cellulose content. Despite the poor digestibility of the protein in silage-based diets, the carcass is of good quality even if animals are slaughtered at weights of 100 kg or more (Sève, Le Dividich and Canope, 1976).

Fresh or ensiled green bananas can constitute a basic feed for the gestating sow (Le Dividich and Canope, 1975). Farrowing performance (number and average weight of piglets in the litter) is not affected by the inclusion of bananas in the ration. On the other hand, even with a generous supplement (1.0 kg of molasses + 1.5 kg of a feed containing 40 percent protein), bananas do not cover all the energy requirements of the lactating sow. The 5- to 9-kg weight losses that have been recorded indicate that the use of bananas as feed for lactating sows is not advisable. These conclu-

Table 4. **Feeding value of diets based on fresh green bananas and banana silage for growing and finishing pigs (30 to 90 kg live weight)**

		Diets			
		A	B	C	D
Composition of feeds offered					
Fresh green bananas		*ad lib.*	*ad lib.*	*ad lib.*	—
Control diet [1]		—	—	—	*ad lib.*
Raw cane sugar for pigs weighing 30 to 50 kg	*g/day*	400	400	400	—
Concentrate [2] for pigs weighing 30 to 50 kg	*g/day*	600	600	600	—
Concentrate [2] for pigs weighing 50 to 95 kg	*g/day*	900	900	900	—
Apparent digestibility		*Percent*			
Dry matter		[a]84.0	[b]80.6	[c]76.6	[b]79.4
Nitrogen		[a]73.0	[a]71.1	[b]68.7	[c]83.5
Feed intake		*Kg/day*			
Bananas		[a]4.60	[b]3.87	[b]3.93	—
Total dry matter intake		1.80	1.88	1.80	2.42
Growth performance					
Average daily weight gain	*g*	[a]432	[a]434	[a]400	[b]631
Feed conversion ratio (kg dry matter/kg gain)		4.24	4.36	4.48	3.87
Carcass yield					
Dressing percentage		[a]69.7	[a]69.7	[a]68.9	[b]71.8
Average backfat thickness	*mm*	[a]23.6	[a]25.8	[a]24.8	[b]30.6

SOURCE: Le Dividich and Canope, 1975.

NOTE: Averages with the same index letter are not significantly different $P < 0.05$.

[1] Composition: ground barley 70%; soybean meal (44% C.P.) 20%; alfalfa meal 5%; mineral and vitamin premix 5%. — [2] Composition: soybean meal (44% C.P.) 90%, minerals + vitamins 10%.

sions agree with those of Clavijo and Maner (1969).

Banana pulp flour (72.3 percent starch, 1.2 percent crude fibre and 4.5 percent crude protein) was used successfully in weaning feeds for piglets at 5 weeks of age (Le Dividich and Canope, 1974), and even at 3 weeks (Le Dividich [unpublished]). When it comprised 50 percent of the weaning feed, growth performance was comparable to that obtained with cassava flour. It also facilitated keeping the animals in excellent health (as noted by the lack of diarrhoea), which is an important consideration in the choice of weaning feeds.

Thus, the use of fresh and ensiled bananas in pig feeding contributes to considerable savings in concentrate feeds. Such savings may amount to about 50 percent per pig slaughtered at 95 kg live weight (with a good lean carcass) and 75 percent per gestation (without affecting farrowing performance). However, fresh bananas should not be used in early weaning feeds because of the piglet's poor capacity to digest starch from this source. On the other hand, flour made from green bananas is well tolerated by piglets when they weigh 5 kg or more.

Use in ruminant feeding

Only a limited amount of work has been done on the use of bananas for ruminant feeding.

Banana pulp flour. Bananas have hitherto been used after dehydration as a source of starch for the preparation of calf feeds. The flour is used in the manufacture of milk replacers in substitution for lactose. However, its use is restricted to particular situations. It is known that preruminant calves can be fed to high slaughter weights if the lactose and some of the fats are replaced by starches; the substitution promotes protein synthesis (Thivend *et al.*, 1972). This would suggest that at a time when the use of cereals in animal feeds is being increasingly questioned, banana flour should find special favour as an ingredient in calf feeds.

Some work has been done, notably in Ecuador (Spiro, 1973; Rihs *et al.*, 1975), on the introduction of banana flour into ruminant diets. Spiro demonstrated that green banana flour could replace 50 percent of the cereal in feeds for young growing and finishing cattle without changing their intake and growth rates.

Fresh and ensiled bananas. The conversion of bananas into flour is a costly process and may be justified only for preruminant calf feeding for the production of veal, which represents a luxury commodity. For milk production or conventional meat production, however, it is preferable

Table 5. **Influence of different kinds of energy and nitrogen supplementation on feed intake and milk production in dairy goats**

Energy source		Cereal		Green banana		Ensiled banana	
Nitrogen source		Soybean cake	Soybean cake + urea	Soybean cake	Soybean cake + urea	Soybean cake	Soybean cake + urea
Level of urea (N as % total N)		(0)	(32.2)	(0)	(28.9)	(0)	(28.5)
Dry matter intake				*g/day*			
Pangola (regrowth of 50 days)		679	686	176	321	319	330
Bananas		—	—	1 330	1 278	1 099	904
Concentrate		828	749	448	189	404	160
Total dry matter intake		[a]1 507	[b]1 435	[c]1 954	[d]1 788	[d]1 822	[b]1 394
Dry matter intake per 100 kg live weight	*kg*	3.14	3.34	4.17	3.26	3.67	3.24
Milk production	*kg/day*	1.627	[b]1.481	[c]2.028	[a]1.599	[d]1.878	[b]1.447
Butterfat content	*g/kg*	25.8	26.3	25.4	30.0	27.0	27.5
Concentrate/milk	*g/kg*	509	506	221	118	215	111

SOURCE: Geoffroy [unpublished data].
NOTE: Averages with the same index letter are not significantly different $P < 0.05$.

to use bananas with a minimum of processing.

It was in this context that the work carried out in Guadeloupe, and more recently in Costa Rica, was geared to the use of bananas either fresh or ensiled. In these studies two approaches were followed, one involving the use of bananas as an energy supplement to green forages, and the other using bananas as a basic ingredient of compound feeds that were balanced with fibre, protein, mineral and, where necessary, energy supplements.

1. *Use as a supplement to green forages.* The first series of digestibility trials conducted with goats in cages (Chenost *et al.*, 1971; Geoffroy and Chenost, 1973; Chenost *et al.*, 1976) provided the following results:

— In *ad libitum* feeding, when forages and bananas were offered separately in the trough, the two feeds were ingested in such proportions that bananas constituted 20 to 40 percent of the total ingested dry matter.

— When bananas were blended with forages, it was found that the intake of both dry matter and digestible organic matter rose sharply with increasing content of bananas in the ration from 0 to 20 percent; dry matter intake was higher for ensiled than for fresh green bananas, with a peak of 1.8 to 2.2 kg/100 kg live weight at the 20 percent level. Beyond this level, dry matter intake remained relatively constant as bananas replaced green forage on a weight for weight basis, while digestible organic matter intake rose slowly.

The second series of trials conducted in Guadeloupe (Geoffroy, [unpublished]) with lactating goats demonstrated the feasibility of substituting green and ensiled bananas for all the cereals in concentrate feed. The principal results were as follows (Table 5):

- Total substitution of the cereals with bananas resulted in an increase in dry matter intake.
- Milk production was significantly higher in animals fed green bananas (whether fresh or ensiled) than in those fed cereals.
- The butterfat content remained low and was not affected by the diet.
- Weight gains were significantly higher in animals fed fresh or ensiled green bananas than in those receiving cereals.

The third series of trials with growing goats (Table 6), also conducted in Guadeloupe, showed that half of the conventional concentrates could be replaced with bananas if the ration were supplemented with urea to maintain its nitrogen level (Chenost *et al.*, 1971); the non-protein nitrogen could constitute about 30 percent of the total nitrogen in the ration.

For both milk production and finishing purposes, bananas may be regarded as a good substitute for barley. This was demonstrated in Guade-

Table 6. **Feed intake and performance of fattening kids receiving either Pangola grass supplemented with cereals or bananas, or complete ensiled ration**

		Pangola (ad libitum) diet				Silage diet	
		+ concentrate	+ concentrate with 2.5% urea	+ limited concentrate + green bananas	+ limited concentrate + ensiled bananas	Banana Wheat bran Bagasse Urea	74% 22% 3% 1%
Growth performance							
Initial weight	*kg*	27.3	27.5	27.6	27.8	13.0	
Final weight	*kg*	33.8	34.8	33.6	34.7	35.1	
Duration	*days*	56	56	56	70	156	
Average daily weight gain	*g*	112	130	155	123	142	
Dry matter intake		. . . . . *g/day*					
Roughage		156	198	139	171		
Concentrate		616	616	308	308		
Bananas		—	—	468	510		
Total dry matter intake		772	814	915	989	776	
Feed conversion ratio		6.7	6.2	5.9	8.0	5.3	

SOURCE: Chenost and Geoffroy [unpublished data].

loupe by Poncet (1973), who also observed that banana starch passed into the intestine faster than barley starch, that fermentation in the rumen was less intense and more regular, and that less volatile fatty acids were released with banana rations than with barley rations. The latter observation is consistent with the efficient utilization of urea in both banana-based and barley-based diets.

Cubillos (1974) also used bananas successfully in Costa Rica as a supplement to green forages. Feeding fresh bananas to steers that were raised on grass made it possible to increase stocking rate, the growth rate of the animals and, in consequence, the weight gain per hectare.

2. *Use as a basic ingredient of complete feeds.* In order to simplify feed mixing and feeding, a single feed obtained by ensiling all the constituents of the diet (bananas, bagasse, bran and urea) was offered in Guadeloupe to dairy goats and growing kids. The principal results were as follows (Geoffroy and Chenost, 1973; Geoffroy, [unpublished]):

- The level of silage intake, which was relatively low (2.0 to 2.5 kg/100 kg live weight), increased by 30 to 40 percent when 5 percent molasses was added on a fresh weight basis.

- The performance obtained with this type of feed was promising; milk production was maintained and the growth rate of fattening kids was better than that observed with ordinary cereal-based diets (Table 6).

The results obtained from these studies and applied research suggest that the work begun should be continued in depth. In particular, it would be useful to determine the way in which the different banana preparations affect the digestive and metabolic processes of pigs and ruminants. On the basis of the results obtained so far, bananas may be considered a good energy source for pigs, while in ruminants they are potentially a good substrate for microbial protein synthesis from non-protein nitrogen. This also appears to be confirmed by the work of Herrera and Ruiz (1976), where the substitution of bananas for 50 percent of the molasses in the supplementary energy provided by sugarcane to finishing bull calves resulted in accelerated growth rates and an improvement in feed conversion efficiency.

More generally, in the humid tropical regions it would be interesting to explore the prospects of using local products or by-products in the compounding of complete rations in which the energy component could, for example, be made up chiefly of bananas, sugarcane and molasses, and the protein component could consist of urea and by-products from the cereal milling industry. Sugarcane could be included in proportions that would vary with socio-economic conditions. Adding bananas to sugarcane-based silage could overcome the problems of feed intake and the unfavourable ratios of volatile fatty acids for glucogenesis that were observed by Leng and Preston (1976).

Conclusion

Surplus and discarded bananas are a potential feed resource of great quantitative and qualitative interest in both pig and cattle production. In practice they can be used to replace the entire cereal component of pig and dairy cattle feeds and probably almost all of the cereals in cattle finishing feeds.

The necessary techniques for feeding bananas to pigs have already been developed; it is only necessary to disseminate them more widely and adapt them to varying local conditions. However, some further work on feeding of bananas to cattle is still necessary. In either case, it should be recognized that because of the difficulty of transporting fresh bananas and the cost of dehydrating them, it would be economical to use them as animal feed only in the vicinity of places where they are grown. This limitation is likely to weaken the possible geographical impact of banana feeding. However, the geographical restriction of use to the producing areas is advantageous in that trade in bananas suitable for livestock feeding would be restricted and would not lead to speculative commercial ventures.

Effective local utilization of bananas in livestock feeds would involve the setting up of rearing and/or finishing establishments in the vicinity of banana-packing facilities; this will have the highly beneficial effect of contributing to greater specialization in livestock breeding and finishing operations.

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Processing cattle waste for recycling as animal feed

by Gerald M. Ward and Thomas Muscato

Increasing feed costs and international concern for the conservation of resources have focused attention on the nutrients in animal wastes that have in the past been used largely as fertilizer or as a major source of fuel for villagers in a number of countries. Research and field trials in recent years have demonstrated a variety of other uses for manure, including direct feeding of dried manure, a number of systems for separating or processing manure fractions, conversion to biogas (methane), use as feedstock for synthesis gas, pyrrolysis to produce fuel, and some industrial uses. A comparative study of these alternatives is beyond the scope of this article. These systems have been discussed by Yeck *et al.* (1975) and an analysis of their economic potential has been presented by Harper and Seckler (1975). The feeding value of cattle wastes will be discussed here in relation to alternative methods of handling and processing waste as animal feed.

Dehydrated poultry excreta has a definite place in the feeding of ruminants as described by Smith (1974). The case for dehydrated cattle manure is not as clear-cut because the energy and protein density is considerably lower than in poultry waste due to higher fibre and ash contents.

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Composition of manure

Variations in the chemical composition of cattle manure have been summarized by Azevedo and Stout (1974) and Graber (1973). Table 1 sets out the average analyses of 139 samples collected biweekly over a one-year period from a feedlot in northeastern Colorado, as well as the analyses of samples collected at three locations in the pens: from a concrete apron and from the middle and rear of the pen. Ash averaged 37.1 percent on a dry matter basis, varying from 30.7 to 42.9 percent by location. It was consistently higher when collected from the centre and rear of the pens. Inclusion of soil during scraping presumably caused the increased values. Total nitrogen of all samples averaged 3.67 percent (or 23 percent crude protein on an ash-free basis) and protein nitrogen represented 65 percent of total nitrogen.

Crude fibre content of rations varied from 6.5 to 27 percent and was reflected in the crude fibre content of the manure. P, K, Ca and Na, which are usually present in feeds, were less variable than organic constituents, with mean values of 0.54, 1.35, 1.88 and 0.51 respectively. Heavy metal analysis of Pb and Cd for 25 random samples averaged 1.36 and 1.68 ppm respectively.

The data in Table 2 indicate the influence of cattle diets on the composition of fresh faecal matter. High forage diets result in faeces with a higher percentage of ash and fibre and a proportionately lower percentage of protein. The principal potential nutrients to be derived from cattle manure are fibre and protein. The faeces of grain-fed cattle contain grain fragments, although feeding trials generally indicate nearly complete digestion of starch by cattle and a 75 to 85 percent digestibility of ration dry matter. A complex set of factors influence the extent to which the fibre of feed will be digested by ruminants, including the physical state of feed (i.e. ground, pelleted), the level of intake, and the amount of readily fermented carbohydrate in the ration. The ash fraction of faecal material contains major and minor elements of nutritional value and is probably in a form available for absorption. However, a large fraction of the ash component consists of non-nutritive elements such as silica and aluminium.

Whereas the other components of faeces represent residues remaining after digestion, microbial protein is the result of bacterial growth in the rumen and large intestine (Mason, 1969), and commonly represents a higher quality protein than that found in cattle feeds. The digestibility of the microbial protein in faeces has not been studied specifically, but considerable variation has been found in the digestibility of the crude protein of cattle manure.

Preparation for feeding and use as cattle feed

The simplest approach to refeeding cattle wastes is to remove the air-

Table 1. **Averages of manure constituents**

Location in pen	Dry matter	Total nitrogen (Kjeldahl)	True protein nitrogen (TCA)	NH_3—N	Neutral detergent fibre	Acid detergent fibre	Cellulose	Lignin	Ash
	Percent dry matter								
Concrete apron	53.21	2.61	1.62	0.37	41.42	33.67	6.55	5.25	30.66
Centre	63.51	2.28	1.46	0.29	47.15	38.34	10.06	5.26	37.96
Rear	60.49	2.07	1.34	0.27	49.46	43.08	12.59	5.41	42.90
Average all samples	58.96	2.32	1.47	0.31	45.92	37.98	9.63	5.31	37.14
Average all samples (ash-free basis)	58.96	3.67	2.35	0.47	55.22	45.68	—	8.58	—

SOURCE: Ward, 1976 [unpublished data].

dried waste from feedlots, grind it and mix it in rations. Dried manure added to feedlot cattle rations at levels of 20 to 60 percent has been studied by Ferrell and Garrett (1973), Westing and Brandenburg (1974) and Albin and Sherrod (1975). It was concluded that the manure is nutritionally valuable and that acceptance is not a problem. However, recycling through feedlot cattle removes only about 30 percent of the dry matter of manure. An approach to solving the problem of manure removal is to feed it to cows on winter range. Hull *et al.* (1973) fed 75 percent dried manure pelleted with 25 percent barley to pregnant cows on range. Initially the cows refused the pellets, but a two- to three-week adjustment period resulted in pellet consumption of 5.5 to 8.2 kg per head per day.

Several digestion trials with dried cattle manure from feedlots have been reported (Albin and Sherrod, 1975; Johnson, 1972; Taylor *et al.*, 1974; McClure *et al.*, 1971; and Tinnimit *et al.*, 1972). The results indicate considerable variations in nutrient digestibility. Manure from cattle fed high concentrate rations generally showed a dry matter digestibility of 40 to 50 percent, while that from high forage rations had digestibilities as low as 16 percent (Taylor *et al.*, 1974), although in this case digestibility may have been reduced by the heating temperature of 120°C. Protein digestibility likewise showed a wide range from 15 to 70 percent. A comparison of dried and composted manure indicated that composting improved the digestibility of cell wall constituents, but had less effect on other components (Albin and Sherrod, 1975). Dairy cattle wastes have a higher content of fibre than wastes from feedlot cattle because of the difference in feeding practices. They could be expected to show a lower digestibility in line with the above results. Tinnimit *et al.* (1972) obtained 29 percent digestibility of dry matter and Smith *et al.* (1969) found equally low values for dairy manure from cattle fed an all-forage diet.

Wastelage. Anthony (1970) initiated the idea of "wastelage," a mixture of 57 percent fresh manure and 43 percent hay or hay plus grain. The product is ensiled and undergoes a typical lactic acid fermentation. A series of trials summarized by Anthony (1974) indicated weight gains on wastelage superior to those on grass hay for a period of 389 days for ewes and 332 days for beef heifers. Yearling cattle fed wastelage were slaughtered, and a comparison of meat quality indicated no difference from animals fed conventional rations.

When wastelage containing 60 percent fresh manure and 40 percent

Table 2. **Chemical composition of cattle faeces**

Ration		Lactating Holstein cows		Hereford steers	
		High hay [1]	High grain [2]	Maize silage [3]	High grain [4]
Faeces	*kg/day* [5]	22.2	8.3	8.67	7.83
Faeces	*kg/day* [6]	3.9	1.9	1.89	2.09
Crude protein	% [7]	12.9	18.7	13.0	16.7
Ether extract	% [7]	2.8	2.8	0.9	5.2
Crude fibre	% [7]	41.3	26.1	20.4	12.6
Nitrogen-free extract	% [7]	24.8	44.9	44.3	56.3
Ash	% [7]	29.7	7.4	21.2	9.1

[1] Dairy cows fed cracked maize and alfalfa hay ration 17:83, average weight 500 kg — [2] Same cows fed maize-hay ration 75 25 — [3] Hereford steers fed only maize silage and 0.4 kg protein supplement per day, average weight 364 kg. — [4] Same steers fed 75% maize, 20% maize silage and 0.8 kg soybean oil meal per day. — [5] Wet weight. — [6] Dry weight — [7] Dry matter basis.

Feedlot manure piles could be a valuable source of protein for animal feeds. (Photo: John M. Blanchard)

grass hay was fed to growing steers, it was found that a 40 to 70 percent wastelage ration resulted in weight gains almost equal to the control ration containing 62 percent maize silage (Harpster *et al.*, 1975). Rations containing 100 percent wastelage depressed weight gains by about one half compared to the control ration. The digestion of dry matter by sheep was 66.9 and 47.2 percent respectively when they were fed 50 and 100 percent wastelage.

The digestibility of raw manure mixed with conventional feeds has been studied by Anthony (1970). Of four groups of cattle, two received control rations and the other two received either cooked or washed manure as a fraction of the ration. Treated manure (either cooked or washed) was fed following blending with control ration ingredients at a ratio of 40:60. Dry matter and crude protein digestion coefficients were not lowered by adding manure to the concentrate. All rations were readily consumed and gains of fattening steers were essentially equal to those obtained by animals fed control rations. Cooking or washing before mixing with concentrate did not improve the feeding value.

Other processing methods. Smith *et al.* (1969) studied *in vitro* digestibility of faeces subjected to treatment with alkalis and oxidants. They concluded that chemical treatment enhanced the digestibility of cell wall constituents of ruminant faeces. NaOH was more economical and resulted in non-specific degradation of hemicellulose, cellulose and lignin, making them more accessible to microbial fermentation in the rumen.

A recently described method for processing cattle manure involves the addition of formaldehyde to reduce odour and spoilage and possibly increase the rumen bypass of protein.

The solids collected from an oxidation ditch containing waste from cattle on a high-energy ration was added to a high-energy ration for feeder steers at levels of 5, 15, or 25 percent on a dry matter basis. The solids were estimated to have 50 percent of the feeding value of maize. Steers needed several days to adjust to the rations containing the solids, and feed consumption declined as the percentage of solids in the ration was increased (Hegg *et al.*, 1975).

Several industrial processes have been developed to exploit the fact that cattle manure can be fractionated into a high-fibre, high-ash, liquid fraction containing a higher percentage of protein and digestible energy. However, the latter fraction requires drying before it can be utilized in most rations. A firm in Colorado has designed plants to accomplish this separation. Their ensiled high-fibre product has a feed value for cattle nearly equal to that of maize silage, while rations containing the dried high-protein (23 percent) fraction resulted in about three fourths the nitrogen retention of a control ration containing soybean meal. The dried high-protein fraction, when fed at 15 to 30 percent of the ration, was compared with conventional protein sources in rations for layers and broilers, and for trout, and resulted in similar growth or egg production (Ward *et al.*, 1975). No clinical

symptoms or histopathology associated with feeding the firm's products were found in any of the animals in the feeding trials.

Another fractionation process developed by a firm in Arizona produces a pelleted feed containing 20 percent protein and 14 percent insoluble ash. No increased accumulation of heavy metals or chlorinated hydrocarbons resulted from feeding this product at 8 to 10 percent of the ration (Senior, 1974).

Research and field trials in recent years have demonstrated a variety of uses for manure, including blending with other ration ingredients in industrial plants. (Photo: John M. Blanchard)

Use as poultry feed

Low energy and protein density have limited the use of dried manure in cattle feeding, although before the discovery of vitamin B_{12} cattle manure was fed to poultry as a source of the "animal protein factor" (Hammond, 1942).

Palafox and Rosenburg (1951) included oven-dried and air-dried cow manure in layer and breeder rations at levels of 5, 10 and 15 percent of the diet. Egg production, hatchability and body weight were equal to control up to the 10 percent level. No significant differences were observed in shell thickness or egg quality, but higher levels of dried cow manure produced darker yolks. No androgenic potency was noted, and it was concluded that dried cow manure supplies essential nutrients, especially for hatchability.

Lipstein and Bornstein (1971) observed no toxic effects when dried cow manure was fed to very young chicks; however, it produced decreased growth rates and feed utilization in broilers due to the low content of metabolizable energy.

Health and regulatory aspects

One of the major limitations to recycling animal waste is the potential hazard from pathogens and non-nutritive feed additives. But it should be recognized that cattle are constantly exposed to microbial organisms when they sleep, feed, lick and nibble on manure in feedlot corrals. They also harbour a large microbial population in their digestive tracts.

No clinical abnormalities have been reported in any of the feeding trials listed above. Johnson *et al.* (1975) studied the pathological and parasitological effects of feeding up to 15 percent ground feedlot waste to yearling calves, and concluded that this level had no measurable effect on animal health. Heating manure to 120°C may achieve sterilization, but nutrient digestibility may be sacrificed (Taylor *et al.*, 1974). Reduction of moisture to less than 25 percent by low heating appears adequate; wet manure may provide a favourable environment for pathogen growth during storage.

Wastelage (McCaskey and Anthony, 1975) offers a product with a pH of 4.2 to 4.5 which at a temperature close to 35°C appears to destroy or inhibit pathogen growth to the extent that no abnormalities were produced in long-term feeding trials.

Feed additive residues are another potential hazard, but additives are now less extensively used in cattle feeding than formerly. Federal regulatory agencies in the United States have not given approval for feeding animal waste, but currently the Departments of Agriculture in three of the States have published guidelines for feeding dried or processed wastes. The United States Food and Drug Administration regulations state that the use of poultry manure or litter as a feedstuff for animal feed is not sanctioned, but cattle manure is not mentioned specifically. Taylor *et al.* (1974) have outlined what the FDA considers necessary for acceptance of animal waste as a feedstuff. In 1973 United Kingdom regulations did not prohibit the addition of manure to feedstuffs, but the EEC countries prohibited adding manure or litter to feedstuffs (Blair and Knight, 1973). Feedlot waste apparently is acceptable as a feedstuff in Mexico (Martin, 1974).

Conclusions

Research studies have clearly demonstrated that cattle waste will be eaten in large quantities by cattle and sheep, and that it contains nutrients that can be utilized. Protein is the most valuable nutrient. The feeding trials reviewed in this article indicate the wide variation encountered in the nutritive value of cattle manure. This is attributed to differences in the ration fed, the surface

from which the manure was collected, and storage or drying conditions. Manure from cattle fed high forage rations generally has a low feed value.

The loss of nutrients under natural drying conditions is not well documented but is certainly important. Although cattle manure has been artificially dried for use in feeding trials, it seems unlikely that this would be economic under commercial conditions. Drying at high temperatures may depress digestibility. Fresh manure has a higher feed value, but it cannot be mixed directly in rations. It can be ensiled with other feeds if an adequate collection system and silos are available.

Manure can be chemically treated to improve the digestibility of fibre, but the process has not been economic. Processing methods to separate a major part of the fibre and insoluble minerals have been developed, but expensive machinery and drying of the high-protein fraction from manure are required. This protein fraction has been shown to be of value to both cattle and non-ruminant animals.

Feeding trials with fresh or dried cattle manure and manure products have not resulted in any evident disease or pathological conditions. Nevertheless, the practice is not widely approved by regulatory agencies. No differences in the quality of meat from animals fed waste have been detected, nor has there been a problem of consumer acceptance in cases where it was studied.

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Complete diets fo

by J.B. Owen

The complete diet system for feeding dairy cattle — a radical departure from conventional individual rationing methods — involves the self-feeding of mixed diets based on a variety of available ingredients. The objective of the system is to simplify the process of feeding dairy cows so as to save labour and reduce capital costs on buildings while providing each cow with a well-balanced feed intake on a least cost basis.

In the developed countries the use of complete mixed diets is now almost universal for pigs and poultry, and the emphasis in feed formulation is on the provision of a restricted number of standard diets appropriate to the stage of production of large groups, on a least cost basis. Dairy cattle, however, have been treated on a much more individual basis, with feed ingredients fed separately at specific times of day. Attempts are made not only to feed concentrates to each cow individually, but to adjust allowances frequently according to the level of production (Ministry of Agriculture, Fisheries and Food, Department of Agriculture and Fisheries for Scotland and Department of Agriculture for Northern Ireland, 1975). Self-feeding of complete mixed diets to beef cattle in large feedlots has become a popular feeding system, particularly in the United States, but application to dairy cows is a more recent development. Enough experience has now been gained in this field to ensure safety and efficiency in feeding valuable high-yielding dairy cows.

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Mixed or separate diets?

Ad libitum feeding has obvious advantages, and many farmers in the United Kingdom and elsewhere are already using systems based on self-

A system of self-feedin complete diets simplifies the feeding procedure, maintains high production, and allows efficient feed use.

airy cattle

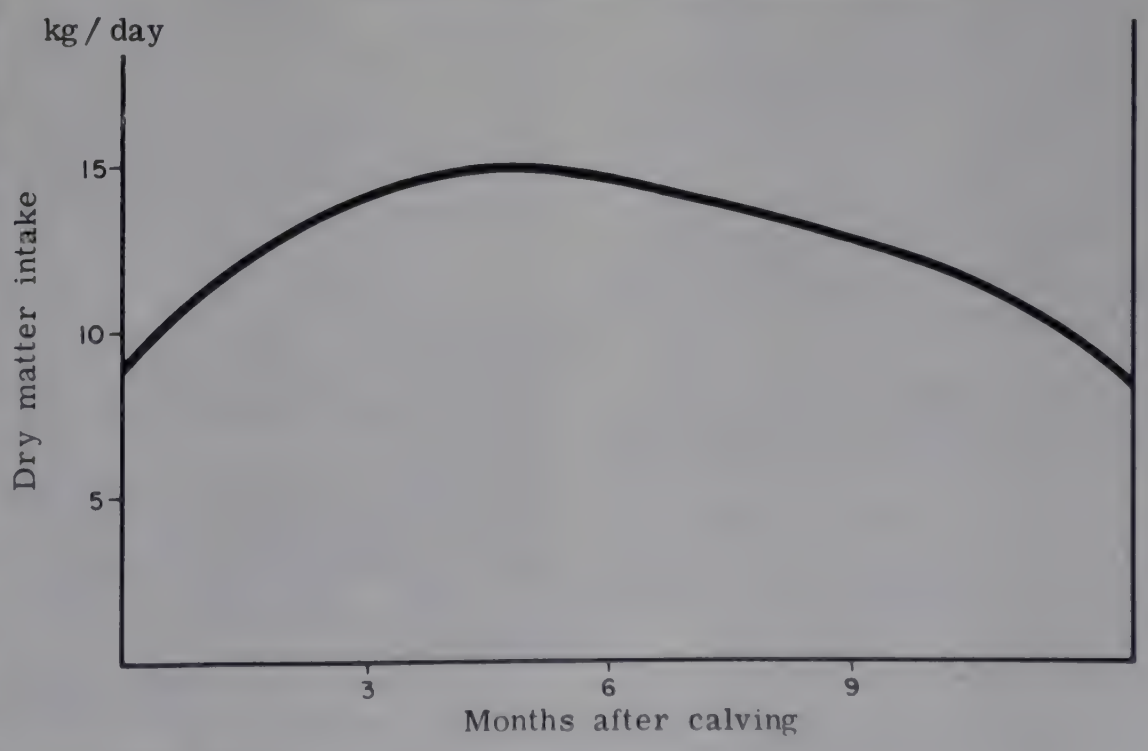
(Left) Feeding complete wet diet from a mixer trailer

feed silage. Unfortunately, the evidence available indicates that allowing dairy cows continuous and simultaneous access to roughage and concentrates, but in separate hoppers, leads to inefficient overconsumption of concentrates. An even more serious result is that the roughage content of the diet can fall below the minimum safety level for the high-yielding cow so that rumen function is impaired, milk fat content is reduced, and lactation inefficiency and predisposition to digestive upsets may be experienced (Owen *et al.*, 1968). A mixed diet containing an optimum proportion of roughage, according to the stage of lactation, is therefore assumed to be an essential basis for a sound self-feeding system.

Intake/production relationship

An efficient feeding system must allow some adjustment of feed input according to nutritional need or output. Even in conventional systems where concentrates are strictly rationed, there is still considerable scope for variation in the total intake because of the flexibility in *ad libitum* roughage intake and differences in body size, as some cows, through inclination or social pressures, consume relatively less roughage than others. Recently, the idea that "flat rate" group feeding of concentrates to dairy cows can be just as efficient as individual rationing in many circumstances (Broster, 1975) has been gaining increasing acceptance. Therefore, a self-feeding system based on a diet broadly adjusted to the stage of lactation should be acceptable, and has the advantage of eliminating differences in the roughage/concentrate ratio among cows. Furthermore, it has been demonstrated (Owen *et al.*, 1968; Monteiro, 1972; Greenhalgh and Reid, 1975) that within the limits of the lag of response in early lactation, voluntary feed intake by the dairy cow is associated with milk output during lactation (Figure 1). Self-feeding on the

Figure 1. **Pattern of dry matter intake during lactation**



SOURCE: Owen, 1976.

basis of at least two diets according to lactation appears to be an economic means of meeting the needs of the cow. In the period shortly after calving, the system helps to avoid overfeeding of concentrates and the attendant danger of upsetting rumen function.

Dry matter intake

There is evidence that cows allowed to self-feed in groups on an appropriate complete diet tend to achieve a higher daily dry matter intake than those on conventional feeding. This is partly brought about by the processing effect of the mixing equipment, and partly by other more complex and less well understood factors (Allen, 1976; Coppock *et al.*, 1972). This increased intake may enable the energy needs of the dairy cow to be catered for with diets of lower energy content, i.e. higher roughage and lower concentrate content, leading to a reduction in feed costs. The system ensures that no individual cow may consume less than the desired ratio of roughage to concentrates, but allows each cow to maximize its intake within that limitation.

Development work

Following the work in the 1960s on the basic aspects of complete diet feeding, there has been much development work in the United Kingdom at Cambridge University, the Aberdeen School of Agriculture and a number of commercial units, employing a variety of basic feed ingredients. These fall into two main categories:

1. *Dry straw/cereal mixtures.* These diets are based on dry cereal straw (as the roughage basis) mixed with cereals and protein supplements. These can be stored for extended periods so that hoppers can be filled at intervals of several days. The main disadvantage is the cost of processing the straw (by close precision chopping, or by milling through screens with apertures of about 10 to 15 mm) and mixing with the other ingredients.

Examples of diets that have been used on commercial farms in the United Kingdom are given in Table 1 (D. Wilkins, 1975 [personal communication]).

Because of the cost of processing straw, the tendency has been to reduce the straw content to a minimum level of about 30 percent for the loose mix after a period of adjustment using transition diets.

Experience with the system has demonstrated that substantial simplification of the feeding system is achieved in practice with the elimination of parlour feeding, the reduction of feeding space, the reduction of feeding chores through mechanized feed preparation, and the replenish-

Table 1. **Comparison of conventional and self-feeding practices**

		Conventionally fed group	Self-fed group
Grazing hectares		28.7	20.6
Conserved hectares		22.3	—
Cereal hectares		20.6	24.3
Total hectares		71.6	44.9
Purchased concentrates	*tons*	22.8	30.6
Purchased molasses	*tons*	5.94	10.6
Purchased stock feed potatoes	*tons*	61	—
Milk produced	*kg*	284 448	253 159
Yield per cow	*kg*	4 548	4 602
Total solids	*%*	12.10	12.32
Hectares per cow		0.96	0.59
Calving index	*days*	395	357
Diet composition [1]		. . . . . *Percent*	
Winter diet			
Protein concentrate		[2] 20	15
Barley		[2] 75	50
Molasses		[2] 5	5
Straw		—	30
Summer diet			
Protein concentrate		[2] 10	7.5
Barley		[2] 85	57.5
Molasses		[2] 5	5
Straw		—	30

SOURCE: Based on a study undertaken on a commercial farm in Cambridge, United Kingdom, using a Friesian herd split into two groups for two years.

[1] Fresh weight basis. — [2] Concentrate allowance only.

Table 2. **Comparison of winter feeding of conventionally fed and self-fed groups of dairy cows**

	Conventionally fed group (25 cows)		Self-fed complete diet group (25 cows)			
			Early lactation		Late lactation	
	Early lactation (daily allowance)	Late lactation (daily allowance)	Fresh weight	Dry matter	Fresh weight	Dry matter
Diet composition	*. . . Kg fresh weight . . .*		*. . . . . Percent . . . . . .*			
Grass silage	18-20	18-20	39	35	40	33
Swedes	16	16	30	12	28	10
Distillers' grains	11	11	21	21	21	19
Barley	7	5	8	27	7	23
Protein concentrate according to yield in parlour				2	5	1
Straw	—	—	—	—	3	10
Metabolizable energy content (MJ/kg DM)	5	5	4	10		8.5

Performance during trial period			
Average daily yield	*kg*	19.5	18.6
Concentrates (barley + protein concentrate)	*kg/cow*	1 410	939
Calving to conception interval	*days*	78	73
Weight change	*kg*	+11	+11

ment of feed hoppers at intervals of several days; this, incidentally, allows exclusion of week-end feeding chores.

Commercial farm experience has shown that yields, milk quality and breeding regularity tend to improve under the system (Table 1). Although these findings are not based on rigorously controlled experiments and may largely reflect certain inadequacies in the conventional feeding system, they seem to point to a real value of the system, i.e. that it ensures high performance under a variety of circumstances and managerial skills.

2. *Wet mixtures of silage/concentrates.* Many dairy farmers use silage and other wet materials in diets for their dairy cows. In northern Scotland, grass silage, wet distillers' grains and roots with a high water content (e.g. swedes and turnips) often form the basis of winter feeding. Common systems of silage making involve precision chopping so that there is little difficulty in incorporating such material into a complete mixed diet. Roots, however, need suitable processing prior to incorporation, and even then some degree of selectivity can be exercised by the cow. Experience at the Aberdeen School of Agriculture (Allen, 1976) has shown that satisfactory results can be obtained by mixing wet and dry ingredients either in a specialist mixer trailer or by using less sophisticated conventional forage boxes where the ingredients are loaded in even layers so that mixing is accomplished as the material is dispensed into the feeding trough.

One apparent advantage of the specialist machine is the increased density of the resulting mixture due to the squeezing action of the augers.

Figure 2 shows the composition of a mixture of silage, distillers' grains and barley after processing in alternative mixing systems. The increased density and lack of aeration of the mixture give the material better storage properties, so hoppers do not need filling at the week-end — a powerful attraction for many dairy units where long working hours are a pressing problem. Table 2 summarizes results obtained in a development trial at Aberdeen.

Conclusions

As a result of the above development work, several important conclusions may be drawn:

1. Self-feeding of complete diets is capable of maintaining milk yield and quality in dairy herds that were formerly well managed on a conventional system. In some cases it has been the means of correcting inadequacies in conventional feeding and thereby raising yield and milk quality. The maintenance or improvement of production has normally been accompanied by savings in concentrated feed and more intensive use of roughage components.

2. The results have been achieved with a marked simplification of feeding routines allowing complete or partial replacement of feeding in the milking parlour and the restriction of feeding chores to once a day or less frequently during the week, and the elimination of week-end feeding work. The management and labour force in the units associated with these developments have reacted favourably to the adoption of the system.

3. Continual access to feed has allowed feeding space at the trough to be reduced. Figure 3 shows the dimensions of a feed trough suitable for a silage-based mixture. The saving in feeding space on the design of dairy units is far-reaching; for example, covered concrete feeding areas can be substantially reduced as compared to a unit based on more orthodox feeding methods, and thus lead to a substantial saving in capital cost.

4. There are two important and related safety aspects to be emphasized in self-feed systems:

(*a*) During the period of adjustment to self-feeding, a regime of transition diets must be adopted to avoid the danger of digestive upsets and acidosis through overeating. This involves changing from pasture feeding or conventional feeding by initially allowing free access to a diet containing a high level of roughage only. A starting diet containing 70 percent roughage (silage, hay or straw) in the dry matter has been found suitable under a variety of circumstances. The diet is adjusted to the required level of roughage over a period of about two weeks. Dairy cows can be changed to the system at any period of the lactation, although there are advantages in achieving transition before calving where this is possible. (*b*) Care must be taken to ensure a continuous round-the-clock supply of feed, although prudent stockmen adjust daily allowances to minimize, but not eliminate, carry-over of surplus from one day to the next. If for some reason the feed does run out for a period of four hours or more, it is advisable to adopt the transition procedure (i.e. using the higher roughage level for the first feed following a period of feed deprivation), although transition to the normal level can be relatively rapid, depending on the length of the period of accidental deprivation.

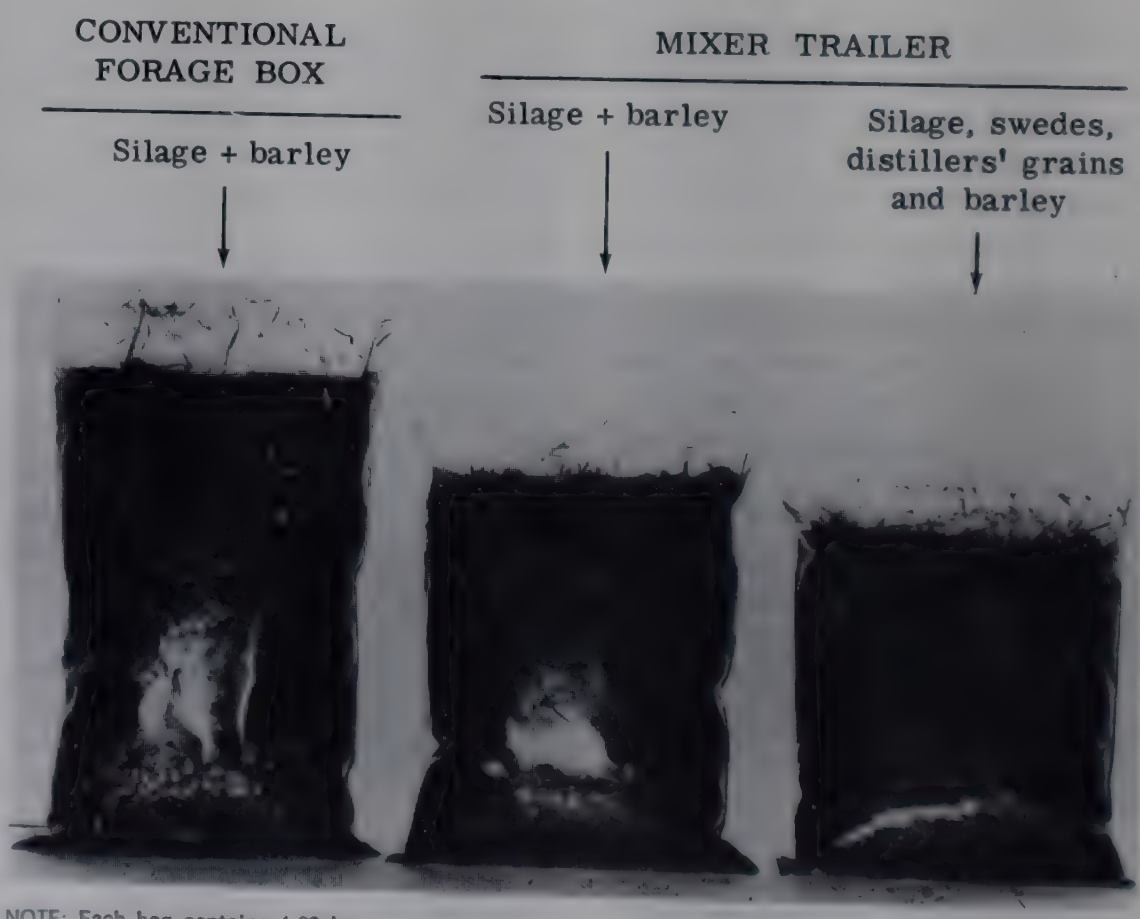
5. Development work has not identified a need for filling the feed hoppers more often than once a day, whatever the type of diet used. In many large beef feedlots it is still customary to feed twice a day; this may be because adjustment of feed allowance to reduce surplus can be achieved with less danger of the animals being without feed for any length of time. Another factor is that in large units, feeding twice a day may have no significant effect on either the labour requirement load or the transport cost.

Avoiding week-end feeding is a possibility with many mixed diets, provided they are suitably processed and the feed container is suitably designed to allow for a sufficient capacity of feed to be continually within the cow's reach.

6. The system ensures that the feeder can dictate the roughage content of the diet of each cow. This is an important advantage for safeguarding health and milk quality and ensuring a high level of roughage intake. Traditional thinking about individual rationing of dairy cows implies that the choice of a single optimum roughage/concentrate ratio for group feeding would be difficult and ultimately wasteful; in practice, however, the decisions on diet formulation resolve themselves rather simply.

With good dairy breeds in early lactation, most situations favour a

Figure 2. **Effect of processing on diet**



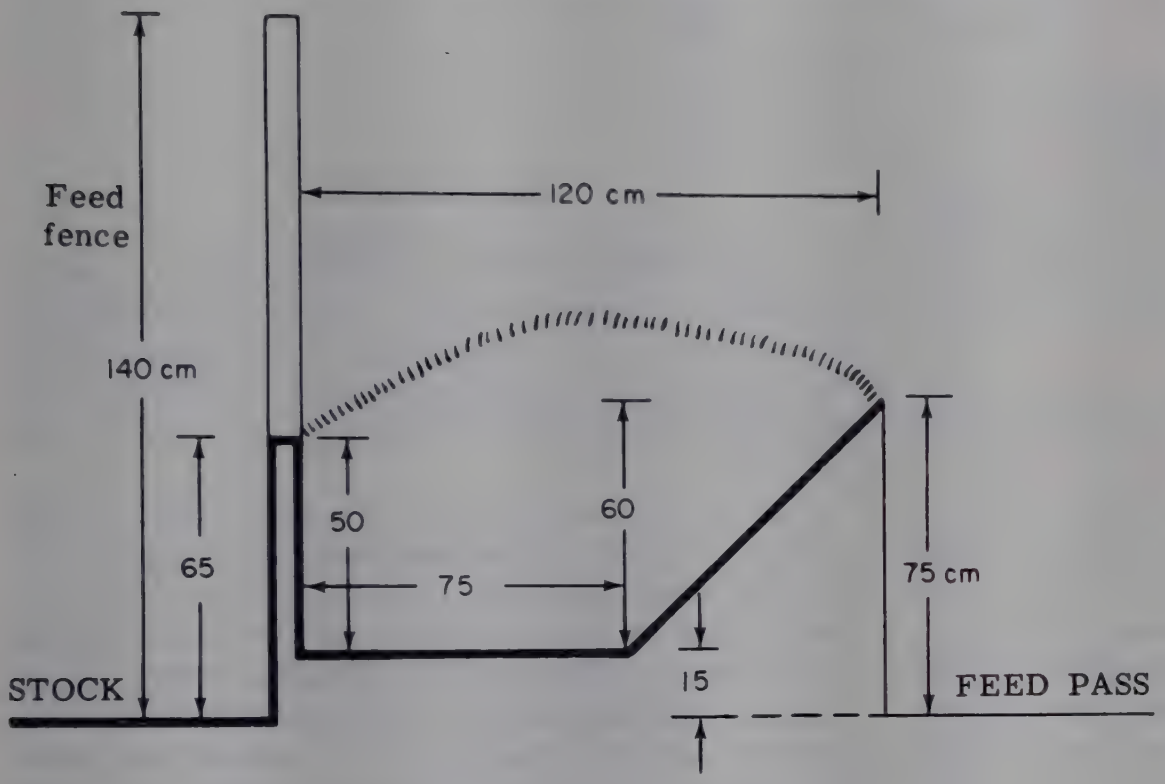
NOTE: Each bag contains 1.36 kg.

high proportion of concentrates giving a total dietary ME concentration of 10-12 MJ/kg DM, provided the roughage is in a "coarse" form (either chopped or very coarsely ground). The extent to which this level is reduced in later lactation to a minimum of about 8 MJ/kg DM and the manner of reduction depend on the type of cow, the relative costs of roughage and concentrates, and the particular circumstances of the unit.

In some commercial units the herd is divided into two groups according to calving, and the composition of the diet offered to any group is adjusted one to three times during the production cycle so as to give two to four diets over the year. With the knowledge that two diets provide a safe norm, the producer will be able to adapt his own procedure with experience to suit his own local circumstances.

7. A specialized application of the use of self-fed complete diets is as an adjunct to heavily stocked pasture. This ensures full utilization of pasture production without subjecting the cow to a fluctuating energy intake. In this case, complete diets are offered *ad libitum* and are so formulated that the cow exerts the right grazing pressure before any substantial change to a higher intake of feed supplement is made. Experience at the Aberdeen School of Agriculture (Allen, 1976) has shown that cereal/straw mixtures of the kind suitable for mid-lactation feeding can be successfully used for this purpose, and can lead to substantial savings in the area of grass used by the dairy herd. This system would be particularly applicable in areas where grass growth is uneven and unpredictable.

Figure 3. **Feed trough giving easy access and storage space**



SOURCE: E.R. Harrison, 1976 [personal communication].

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The outbreaks of foot-and-mouth disease and swine vesicular disease in Malta

by G.W. Ford

The three islands comprising Malta have a total land area of about 316 km² and a population of 300 000. The livestock population comprises 80 000 cattle, sheep, goats and pigs that are susceptible to foot-and-mouth disease. Of these, about 50 000 are pigs.

The 1975 outbreak of foot-and-mouth disease was the first in nearly thirty years, and there was no record of swine vesicular disease; however, both diseases had occurred on many occasions in neighbouring countries bordering the Mediterranean. The relative freedom from disease enjoyed by Malta was largely attributable to the strict preventive measures enforced because of the high density of both human and animal populations. Meat imports from countries where foot-and-mouth disease was endemic were prohibited. In case meat, fodder and feed were being imported from a country which had an outbreak of the disease, imports were suspended until at least two months after the end of the last known outbreak. Any live susceptible animals that were imported were appropriately quarantined. But one preventive measure that was not effectively practised was the control, destruction or prohibition of entry of swill at the sea ports and airport. However, because of the continuing risk of foot-and-mouth disease outbreaks in Malta, basic planning against such an eventuality was undertaken. This included periodic discussions between the Senior Government Veterinary Surgeon in Malta and FAO Headquarters staff, as well as guidance from the latter. Nevertheless, when the outbreak did occur, many of the arrangements had to be made on an *ad hoc* basis. Fortunately, since Malta's internal and external communications are very good, it was possible to make the eradication plans very quickly.

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First outbreak

The first outbreak of foot-and-mouth disease occurred on 5 June 1975 on a pig farm. Samples of suspected pig carcasses were sent immediately to the Animal Virus Research Institute (Pirbright, United Kingdom), which diagnosed foot-and-mouth disease caused by the type "O" virus.

The first outbreak was on the east coast. It was therefore hoped that the prevailing northwesterly wind and the usual hot weather during the month of June would assist the eradication process. Unfortunately, the northwesterly wind was not as strong as usual, and on occasion even came from the opposite quarter, and there were not many hot sunny days. A series of vital countermeasures were therefore planned. Not all of them were brought into force at once because it was not easy to bring home to the authorities and to the farmers concerned the seriousness of a disease that had never before significantly affected the country. Moreover, with only one outbreak on a relatively isolated farm, it was hoped that perhaps the first control measures taken would be adequate.

Control measures. The first measures taken included the destruction of all susceptible animals on the infected farm, the disinfection of the farm, the isolation of the farm and the farmer, and the issue of warnings to all other livestock farmers to keep their animals under cover. But perhaps the most important measure taken was the decision to vaccinate all susceptible animals in the islands, with priority given to animals nearest the infected farm. Malta had never before vaccinated its animals against foot-and-mouth disease. It was thus necessary to train teams quickly to carry out this work. It was also necessary to obtain "O" type vaccine at short notice. Fortunately, this was received very quickly from the Animal Virus Research Institute.

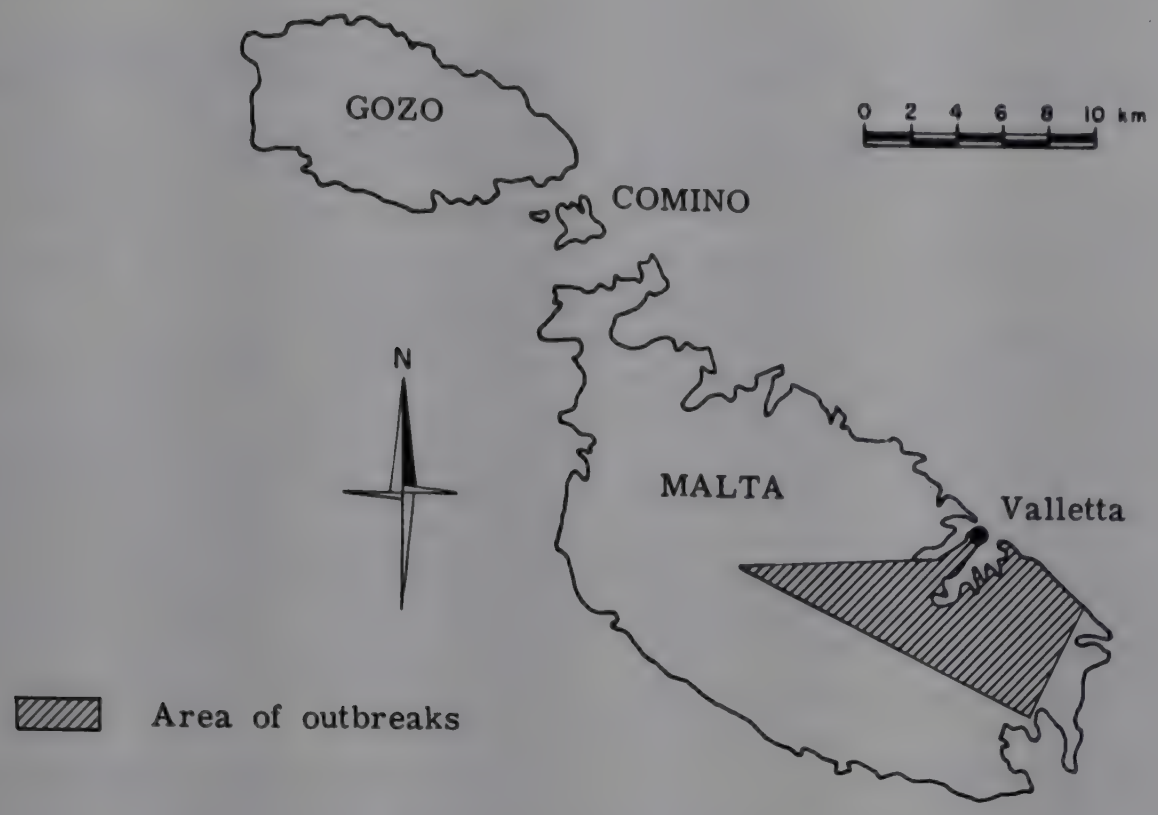

Figure 1. **Area of foot-and-mouth disease outbreaks in Malta in 1975**

Later outbreaks

However, the first control measures proved to be inadequate. Nine days after the first outbreak, two more were identified, and on subsequent days there were further outbreaks. It thus became evident that the disease had spread before effective isolation of the first infected farm was achieved, and before the vaccine was able to provide sufficient protection. It also became clear that Malta's small veterinary staff would not be adequate to contain the disease.

Further control measures. It was therefore decided to secure additional veterinary assistance from the United Kingdom and elsewhere. The services of a team from the Animal Virus Research Institute (team leader Dr. John Watson, some 20 veterinary surgeons, two scientists and three senior technical assistants) were made available to combat the disease. In these circumstances, it was not necessary to take advantage of FAO's offer to send an animal health officer.

At first glance it might seem that 20 veterinary surgeons were an unnecessarily large contingent; however, some of them not only undertook "combat" work, but were also engaged in teaching and training the hastily assembled corps of veterinary assistants, and while this corps was being trained, some of the veterinarians had to perform tasks that were later taken over by assistants. The success of the campaign was demonstrated by the fact that despite the congested conditions of Malta, there was a total of only 24 outbreaks, and these were contained within a relatively narrow segment of land comprising about one fifth of the area of Malta. Furthermore, no outbreaks occurred on the neighbouring islands of Gozo and Comino.

Numerous other measures were also adopted. An operations control centre was established in a wing of the local prison, which was just outside the infected area, and an adjoining prison building was established as a decontamination centre for the teams that visited the farms. The movement of all animals was prohibited except under licence, and this was only granted following a veterinary inspection of the herd. The movement of farm-grown animal feedstuffs was prohibited. The abattoir was closed for disinfection and later opened on a restricted basis. The Minister of Agriculture and a Maltese veterinary officer explained on television the general situation and gave detailed advice to farmers, i.e. to keep everyone to the greatest extent possible off the farms, erect a disinfection ditch at the farm entrance and report all suspect symptoms to the veterinary service. An important decision that helped to secure the farmers' cooperation was the promise made by the Government to compensate the owners for all animals slaughtered. These included all infected animals as well as all susceptible animals on the farm where infection was known to have occurred. The burning of carcasses, however, was a difficult problem in a country where there is only a thin

layer of soil over the limestock rock, and where most quarries could not be used because of the water-bearing strata underlying the rock, which is often fissured. Herds were inspected as frequently as possible. Infected farms were cleaned and disinfected — a formidable problem because large accumulations of dung and other debris had to be dealt with. The police and the animal welfare organization cooperated in rounding up the many stray dogs. Improved control measures were established with regard to swill arriving at the sea ports and airport. Special precautions were taken to keep the disease out of the islands of Gozo and Comino: disinfection was established at the points of exit and entry, and restrictions were placed on Gozitans visiting Maltese farms. The Government's artificial insemination service for cattle was suspended. It was decided that fresh milk would continue to be accepted from non-infected farms, but the state dairy took many special disinfection and cleansing measures at the milk reception depots and processing dairies. Horse races and agricultural shows were prohibited. The Chief Government Medical Officer also appeared on television in an endeavour to allay the anxiety of the public from a medical point of view; however, there was a marked (though temporary) decline in consumption of meat, especially pork.

The Institute scientists monitored the disease situation and decided to give a second (booster) vaccination to the animals about one month after the first vaccination. For cattle, sheep and goats, an aqueous inactivated monovalent "O" type vaccine was used, and the tests showed that it provided a good level of protection. For the second vaccination of pigs, a French oil-based vaccine was used in order to produce longer-lasting protection.

There was, however, one desirable precaution which could not be taken. This relates to the widespread practice in Malta of private (licensed) persons collecting domestic refuse from dustbins to use in an unsterilized form for feeding pigs. The Government did not consider it practical during the epidemic to prohibit this system, or to cause the swill to be sterilized.

Last outbreak

The last outbreak of foot-and-mouth disease occurred on 3 July 1975, and the various follow-up measures took another six to seven weeks to complete. Thereafter it was possible for the veterinary service to return to normal working conditions.

By the end of the 1975 outbreak 251 cattle, 25 sheep, 155 goats, and 1 368 pigs had had to be destroyed; these represented just over 2 percent of the total number of susceptible animals in Malta. The source of the original outbreak was not ascertained, but there was considerable evidence pointing to infection from imported swill.

By March 1976, there was no recurrence of foot-and-mouth disease, and a third vaccination had been completed. It is hoped that this vaccination, together with a more effective control of swill at the sea ports and airport, will provide a sufficient safeguard in the future.

Outbreak of swine vesicular disease

On 28 August 1975 a suspect case was reported from a herd of pigs in the centre of the island of Malta. On this occasion, the Institute diagnosed swine vesicular disease. This posed a considerable dilemma for the Maltese authorities. No commercial vaccine was available, and the disease spread very rapidly. Fortunately, the disease is limited to pigs, and most affected animals recover. Other countries with the disease have pursued varying policies: in the United Kingdom a slaughter policy is adopted, but many other countries "live with the disease" and endeavour to isolate the farm (or farms) concerned. The biggest problem for Malta was that the disease broke out so quickly after the last outbreak of foot-and-mouth disease. Since the clinical symptoms of the two diseases are similar, there was the very real danger that a further outbreak of foot-and-mouth disease might be wrongly diagnosed locally as swine vesicular disease.

Malta decided not to slaughter the infected pigs, but to keep the farms isolated as far as was practical, and to send samples from infected pigs to the Institute so as to ensure that the disease was in fact swine vesicular disease. This policy did not require the same "mass" attack by the veterinary staff. Nevertheless, there were a number of post-foot-and-mouth disease matters on which advice was required, and so three experts from the Institute returned to Malta and remained there for about a month.

As with the original foot-and-mouth disease outbreak, it was not possible to ascertain the source of the swine vesicular disease outbreak, but it could well have been imported swill. Within a short time, a large number of pig farms were infected in Malta and in Gozo, to which the disease spread on this occasion. It is probable that most pig farms in the islands have now had swine vesicular disease to some degree. In a few instances there were deaths among pregnant sows, in sows that had recently farrowed, and among boars. Some of these animals developed signs of meningoencephalitis before death, but these accounted for less than 0.1 percent of the pigs on affected farms.

The future

The British veterinary team recently provided the Government of Malta with a detailed report containing a number of recommendations for improved veterinary control. The setting up in Malta of a proper system of collection and disposal of garbage has also been recommended by the European Commission for the Control of Foot-and-mouth Disease following the visit made to the country by the Secretary of the Commission in October 1975.

Animal feeds, livestock, milk and milk products: current situation and prospects *

COARSE GRAINS

In 1976 world output of coarse grains is expected to expand by 6% to over 700 million tons, allowing some expansion in consumption and an increase in stocks. With the exception of western Europe, where drought may reduce output by 8 million tons to 84 million tons, coarse grain production is expected to increase in all regions. Of particular importance is a recovery in U.S.S.R. crops and larger maize production in the United States. Among individual grains, output of maize is expected to rise from the 324 million-ton level of 1975 to 336 million tons, barley from 156 million tons to 174 million tons, sorghum and millet from 101 million tons to 105 million tons, oats from 49 million tons to 50 million tons, and rye from 24 million tons to 29 million tons.

Several factors are expected to influence feed demand in 1976/77. In the developed countries economic recovery from the recession of 1974 and 1975 is under way and inflation is less severe. Livestock/grain price ratios have generally improved, although in recent weeks these ratios have become less attractive, mainly as a result of lower livestock prices, and further improvement is required if a substantial increase in grain feeding is to be realized. Lower domestic feedgrain availabilities in regions where crops have been poor are also expected to curb grain consumption and stimulate interest in alternative feeds. But on the whole, feed consumption is expected to grow and contribute significantly to the forecast growth in total grain consumption.

In eastern Europe and the U.S.S.R. feed consumption is expected to increase following the curtailment of growth in 1975/76 due to the low level of domestic production. In western Europe grain requirements for animal feed are expected to increase, as drought has adversely affected pastures and the production of fodder crops. However, total consumption in the region may not expand beyond the level of the previous year, owing to lower domestic production of coarse grains and increased utilization of alternative feeds which are assuming a growing importance in the manufactured feed industry. Larger quantities of wheat are expected to be fed to animals. In North America, the forecast increase in feed utilization is now expected to be less than anticipated, as feed/animal price ratios have recently become less favourable.

Shifts in consumption between grains will reflect changed production patterns. Greater use of wheat as animal feed is projected in Europe, the U.S.S.R. and North America. Increased maize availabilities will offset the tighter supply situation that could develop for other coarse grains. Although world barley and oat production has increased, a sharp fall in supplies held by major exporters may restrict trade and affect global consumption.

Trade in coarse grains in 1976/77 is forecast to be about 70 million tons, down slightly from the previous year. There will, however, be some shift in destination, with the U.S.S.R. taking 6 to 8 million tons as compared with the high level of 13.5 million tons a year ago. Offsetting this will be larger EEC requirements owing to drought-reduced production, and some expansion in Japanese imports. Availabilities from major exporting countries are expected to be sufficient to cover import requirements and to allow for some rebuilding of stocks.

OILSEEDS, CAKES AND MEALS

Current forecasts for the production of the main oilseed and oil crops in 1976/77 indicate only relatively small overall changes from the previous season. World output of *soybeans* is expected to decline, following a 12 percent reduction to 36.6 million tons in the 1976 United States crop. Contrary to earlier expectations, United States carry-over stocks will probably be only slightly larger in September than a year earlier, as both domestic crushings and exports in the 1975/76 season are now estimated at new record levels. The reduction in the United States crop will be partly offset by a further increase to around 13.0 million tons in the Brazilian crop.

The world *groundnut* crop is expected to decline somewhat, as the record harvest of the preceding season in India is not likely to be equalled. Output of *rapeseed* will also fall, mainly because the area sown in Canada was reduced by more than 40 percent. On the other hand, sizable recoveries are expected in the U.S.S.R. *sunflowerseed* crop and the United States *cottonseed* crop. A small reduction is forecast in *copra* output in the Philippines, following a record output in 1976, but *palm kernels* and particularly *palm oil* production will continue to expand, largely on account of larger supplies in Malaysia. Fishing prospects for 1977 are impossible to ascertain at this stage, but there might be a further moderate recovery in Peruvian *fishmeal* output.

World production of *oilcakes* and *meals* is tentatively forecast to fall by 2 percent to 32.1 million tons (protein equivalent) in 1976/77. The decline is practically all accounted for by the reduced output of soybean meal protein, and will be only partly offset by slightly larger beginning stocks of soybeans. Although higher prices for protein feed (in both absolute terms and relative to feedgrains) are tending to dampen demand, consumption is likely to exceed supplies from current production, and stocks may be expected to decline by the end of the season.

Prices have increased markedly during the last three months. The rise began in May, when it was concentrated on oilseeds and oilmeals, as relatively low prices for protein feeds have brought a strengthening of demand. The price increase soon spread to oils and fats as well. Early fears of inadequate rainfall in the United States, substantial purchases of soybeans by the U.S.S.R. and relatively strong import demand for oils from developing countries contributed to an increase in prices. However, prices began to show more uncertain movements in late July. There has been an overall downward trend reflecting good crop conditions in the United States and the realization that demand for protein will be lessened by its higher price relative to feedgrains and to lower profitability of livestock feeding.

* As of 25 August 1976.

MEAT

Unfavourable weather in several major meat producing regions adversely influenced the livestock industry in the second quarter of the year. The downturn of cattle cycles begun in 1975 has been accentuated by bad pasture and fodder conditions. Drought hit parts of western Europe, some eastern European countries and Argentina. In Australia floods in the north and severe drought in the south resulted in losses of livestock. The cattle industry in the United States was favoured by lower feeding costs which contributed to a marked expansion of feed production. Wet and cool weather in the European part of the U.S.S.R. has favoured grass growth and helped to lessen the impact of the tight domestic feedgrain supply situation.

In western Europe *beef* supply increased sharply owing to heavy slaughterings. To avoid a deterioration of beef prices, most drought-affected countries introduced some market support measures, mainly by withdrawing beef into cold stores. EEC beef intervention stocks, which now include cow beef from disaster areas, exceed 300 000 tons and are growing at the rate of 15 000 tons per month.

Pigmeat production in North America may expand markedly in the second half of 1976, but in August commercial hog slaughter in the United States was still about 5 percent below the comparable period in 1975. U.S.S.R. pigmeat production on state and collective farms in the first five months of 1976 was 32 percent below that for the same period in 1975. April pig numbers in the EEC remained practically unchanged from the April 1975 level, with the exception of Ireland and Italy, where numbers were up by 16 and 5.7 percent respectively. Sow numbers increased by 4.2 percent and the number of mated sows rose by 5.2 percent, indicating higher pigmeat production during the coming autumn and winter months.

Supplies of *poultry meat* in the United States and western Europe remained above 1975 levels, and relative price stability in the EEC was maintained by subsidized exports to the Near East and the U.S.S.R.

The relative oversupply of beef in western Europe had a dampening effect on world *meat trade*. Beef imports into the EEC remained controlled during the first half of 1976, and the Community's net trade balance is unlikely to reach the 250 000 tons expected earlier this year. Internal EEC meat and livestock trade also suffered as a consequence of the weakening of the Italian lira and of the introduction in May of a 50 percent import deposit in Italy, now extended until November 1976. In order to boost exports, Australia has introduced an export assistance scheme to non-traditional markets, and Argentina has reduced export taxes on meat. The quota for meat imports into the United States for 1976 was set at 558 000 tons. Japan is expected to import 100 000 tons of beef, mainly in chilled form, during this calendar year. But the country is likely to import less pigmeat than in 1975, and imports of mutton are also expected to fall. To maintain meat consumption in the U.S.S.R. at the 1975 level, imports of over 500 000 tons would be required this year. According to available information, the U.S.S.R. has so far purchased only 25 000 tons of mutton and 10 000 tons of beef from New Zealand and 12 000 tons of boneless beef from Australia. The recently negotiated 10-year trade agreement between Hungary and the U.S.S.R. provides for yearly exports of 18 500 tons of Hungarian beef. As the EEC is considering increasing the export restitution for exports from its beef intervention stocks to certain markets, sales to the U.S.S.R. may again be expected.

MILK AND MILK PRODUCTS

After a substantial increase in the first half of 1976, the rise in world milk output has slowed down in recent weeks, mainly because of drought in parts of Europe and Australia. The economic recovery has been reflected in a new rise in cheese consumption. In the developed countries these divergent trends in milk supply and demand resulted in a drop in the production of butter and skim milk powder below the 1975 level. However, the skim milk powder stocks of the developed countries are still at a record level of over 2 million tons. Butter stocks are also higher than last year.

Notwithstanding the improvement in grazing conditions due to the recent rains, milk output in Europe is unlikely to grow significantly in 1976/77. The cyclical upswing in dairy cow numbers, which had started earlier this year, has probably been arrested by additional slaughterings prompted by the drought. The drought has also resulted in a reduction of hay and other fodder crops, accompanied by an increase in prices of commercial feeds. In western Europe the milk/feed price ratio will be less favourable this autumn and winter than in 1975/76. However, milk production will probably continue to increase in other developed countries, notably the United States, and there should be a further recovery in the U.S.S.R. There will probably be a general increase in the consumption of cheese and fresh milk products, but butter consumption is likely to decline further. Notwithstanding the effects of the drought on European milk output, the excess of supplies over commercial outlets in the developed countries will be reduced only slightly. Measures have already been taken to stimulate consumption of milk and milk products, especially of skim milk powder in the feedstuff sector and as food aid to the developing countries. But in order to restore the balance between supply and demand, further action will be needed to curtail production.

International training course in dairy technology

A ten-week international course in dairy technology will be conducted by the Australian Development Agency from 2 May to 8 July 1977 in collaboration with the Department of Agriculture (Victoria) and the Department of Primary Industries (Queensland). The course is designed to meet the needs of middle-level officers concerned with dairy product manufacture. The following topics will be covered: hygienic milk production, systems of processing milk and milk products, manufacture of butterfat products, quality control, practices relating to building design and product tests, staff training, marketing of dairy products, organization of cooperatives and extension advisory programmes. The States of Queensland, New South Wales and Victoria will be visited during the course.

Participants must be nominated by the external aid authorities of their governments. They should hold a degree or diploma in science, veterinary science or dairy technology, or equivalent qualifications, and should be working in the field of dairy product technology.

Further information may be obtained from Mr. J.B. Lucas, ITC in Dairy Technology, Australian Development Assistance Agency, John McEwen House, National Circuit, Canberra, ACT 2600, Australia.

Fifth international course on dairy cattle husbandry

The fifth course of the series of international courses on dairy cattle husbandry will be held in the Netherlands from 14 March to 17 June 1977. Participants should have had university-level training in agriculture or veterinary science and three years' experience in dairy cattle husbandry or a closely related subject. The course will be conducted in English. Further information may be obtained from the Director, International Agricultural Centre, P.O. Box 88, Wageningen, Netherlands.

Improving ruminant livestock production on small holdings

A seminar report based on the Workshop on Smallholder Livestock Production held at the Winrock Livestock Center, Morrilton, Arkansas, United States from 14 to 17 June 1976 has just been published. The Workshop was sponsored by the Winrock International Livestock Research and Training Center and the Agricultural Development Council (ADC) under the ADC Research and Training Network Programme.

The Workshop brought together persons from major world regions with experience in areas of smallholder and pastoral systems in which livestock keeping is important. Participants and discussion initiators described the role of livestock in the more important smallholder systems; identified the physical, biological, economic and other limitations to the improvement of smallholder livestock enterprises; and recommended methods as well as research and action programmes to improve livestock enterprises and associated resources for the herdsmen and small farmers of the world.

Single copies of the report are available at no charge from the ADC.

FAO/Economic Commission for Europe-Agriculture Division Symposium

The Agriculture Division of the FAO/Economic Commission for Europe is organizing a Symposium on Recent Developments in the Use of New Sources of Protein, Essential Amino Acids and Non-Protein Nitrogen with Special Reference to Ruminants, to be held from 10 to 14 January 1977 at the Palais des Nations, Geneva. The programme will cover nutritional and economic aspects of providing protein (in particular from non-conventional sources) and non-protein nitrogen to dairy and beef cattle. The key papers will be presented by research workers from eastern and western European countries.

In addition to the main speakers, many specialists from governmental institutions, research stations, professional associations and the feed industry are expected to attend. Those wishing to participate should contact their national authorities for registration as members of the national delegation before 15 November 1976. Governments are requested to inform the FAO/ECE Agriculture Division of the names and addresses of their participants.

International Symposium on New Techniques in Veterinary Epidemiology and Economics

The Animal Health Group, University of Reading (United Kingdom) and the Overseas Division of the Brtish Veterinary Association, in collaboration with the Epidemiology Unit, Ministry of Agriculture, Fisheries and Food, organized this symposium from 12 to 15 July 1976 at the University of Reading.

Sessions were held on socio-economic case studies, with particular reference to brucellosis in Australia, the United Kingdom and the United States; foot-and-mouth disease in India, Kenya, and South American countries; a review of techniques, i.e. information systems, epidemiological models of systems simulation; problems of economic analysis and integrated disease control planning.

The third day of the meeting was devoted to a workshop for active workers in the field of veterinary epidemiology and economics.

A report on the symposium, which was attended by approximately 80 participants, will be available before the end of the year.

NEW BOOKS

Methods for the determination of the optimum size of dairy plants and enterprises

International Dairy Federation, place Vergote 41, 1040 Bruxelles, 1976. Document 87. Annual Bulletin. 41 pages. Unpriced. (In English and French)

This publication is divided into five chapters: general theoretical principles, determination of the sizes of divisions, example results of selected production divisions, determination of the optimum size of plant, and determination of the optimum size of enterprise. It is well illustrated, with numerous figures showing variations in processing costs of selected milk products according to levels of production.

This Bulletin would serve as a good introduction to the problem of determining the optimum size of dairy plants and enterprises, and would be of interest to professionals in the dairy sector. Its practical value lies in the information that it provides on methods that may be used in such determinations and on the literature relevant to the subject.

J.R.

EEC programme of coordination of research in beef production

During 1975-76 seven seminars were held under the auspices of the EEC Commission within the Community's programme of coordination of research on beef production. One of the functions of these seminars was to summarize and update the information available on the selected subjects and discuss future needs for research, so as to assist the Commission in evaluating the probable impact of research on agricultural production within the Community.

The proceedings of these seminars are published as follows:

1. *The early calving of heifers and its impact on beef production.* Edited by J.C. Tayler. Seminar held in Copenhagen, 4-6 June 1975. 295 pages.

2. *Perinatal ill-health in calves.* Edited by J.M. Rutter. Seminar held in Compton, 22-24 September 1975. 199 pages.

3. *Improved nutritional efficiency of beef production.* Seminar held in Theix, 14-17 October 1975.

4. *Criteria and methods for assessment of carcass and meat characteristics in beef production experiments.* Edited by A.V. Fisher, J.C. Tayler, H. de Boer, D.H. van Adrichem Boogaert. Seminar held in Zeist, 9-12 November 1975. 406 pages.

5. *Optimization of cattle breeding plans.* Edited by Patricia McGloughlin. Seminar held in Dublin, 26-28 November 1975. 354 pages.

6. *Egg transfer in cattle.* Edited by L.E.A. Rowson. Seminar held in Cambridge, 10-12 December 1975. 416 pages.

7. *Crossbreeding experiments and strategy of breed utilization to increase beef production.* Edited by I.L. Mason. Seminar held in Verden, 9-11 February 1976.

Each book records the texts of the seminar papers and the discussion on them. The participants were chiefly from the EEC countries, but a few visitors from other European countries or the developing countries also attended. The papers cover the subjects very comprehensively; some are reviews and some accounts of research in progress. The last session of each seminar was a discussion of future research requirements with particular reference to coordinated research within the EEC.

The reports are published by and obtainable from:

The Commission of the European Communities
Directorate General, "Scientific and Technical Information and Information Management"
29, rue Aldringen
Luxembourg, Grand-Duchy.

Beef cattle production in developing countries

Edited by A.J. Smith. Centre for Tropical Veterinary Medicine, Edinburgh, 1976. 487 pages. Price: £11, including packing and postage. (In English)

The proceedings of the Conference on Beef Cattle Production in Developing Countries, organized by the Centre for Tropical Veterinary Medicine in Edinburgh from 1 to 6 September 1974, are published in this book. The objectives of the Conference were to discuss the effects of various constraints on beef production and to determine how output of beef can be increased in the developing countries. The Conference was attended by some 200 participants from over 40 countries and involved speakers from many different disciplines, including geneticists, nutritionists, veterinarians, physiologists, economists, agronomists, geographers and social anthropologists. The 31 invited papers that were presented at the Conference are published in full under eight sections, each of which is followed by an edited version of the discussion of the papers in the section. The eight sections relate to international aspects, biological limitations, management, nutrition, climate, genetic improvement, social aspects and economics and marketing.

The book deals with practically every aspect of beef production in the developing countries. The papers and discussions presented cover a very wide range of questions: Should developing countries try to produce beef for export or should they concentrate on the nutritional needs of their own people? Can feedlots be made economic in Africa? In view of the world shortage of sugar, can feeding sugarcane to cattle be justified? How can the Criollo breed of Latin America be saved from extinction in order to provide a basis for exploiting hybrid vigour when it is crossed with the zebu? When cattle have to be taken long distances to slaughter, is it more economic to send them by rail or lorry, or to trek them on foot? Have the deleterious effects of the Sahelian drought been intensified by the control of cattle disease and the provision of watering points without extra grazing? Are similar dangers inherent in a large-scale programme of tsetse fly eradication? On one question at least there seemed to be general agreement — attempts to settle nomads usually have a political aim and cannot be justified on social, economic or ecological grounds.

The book provides a comprehensive and up-to-date review of the problems of beef cattle production in developing countries. It is part of the Centre for Tropical Veterinary Medicine's documentation activities, which aim at collecting, collating and disseminating information on ways and means of improving animal health and production in tropical and sub-tropical countries.

P.M.
I.L.M.

Proceedings of the Lipolysis Symposium

Compiled by W.K. Downey and J.M. Cogan. Annual Bulletin, International Dairy Federation. Document No. 86. Secrétariat Général, place Vergote 41, 1040 Brussels. Unpriced.

The Lipolysis Symposium was held in Cork from 5 to 7 March 1975. This publication consists of 30 working papers which were presented and discussed in five sessions to provide answers to the following questions: How do physiological parameters determine lipolytic susceptibility? Which enzymes are primarily responsible for lipolysis in milk? What are the major causes of lipolytic defects in dairy products? Which technological factors are critical in promoting lipolysis in milk? Which methods should be recommended for monitoring lipolysis? The final propositions arising from the five sessions are summarized in six working papers dealing with physiological factors conducive to lipolysis, enzymic aspects of lipolysis, prevention of lipolysis in dairy products, standard methods for free fatty acid estimation, optimum design of milking machines, and the importance of milking techniques in reducing lipolysis. The proceedings provide an up-to-date account of important facets of the problem of lipolysis in milk and milk products, which perhaps account for the most critical type of off-flavours in these products. The conclusions presented by the International Dairy Federation Expert Group that participated in this symposium reflect the concern of the dairy industry in the control and/or prevention of lipolysis and stress the importance of both biological and mechanical factors. The proceedings represent a valuable addition to the many useful publications of the International Dairy Federation.

F.W.

Correction: *World Animal Review* No. 18, page 15

In the article by L.L. Callow (*Australian methods of vaccination against anaplasmosis and babesiosis*) the sentence reading: "Its combination with relatively avirulent laboratory strains of *A. marginale* alone, specially processed for vaccine, might be necessary" should read: "Its combination with relatively avirulent laboratory strains of *A. marginale* or the use of *A. marginale* alone, specially processed for vaccine, might be necessary."

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Honduras	Editorial Nuevo Continente S. de R.L., Avenida Cervantes 1230-A, Apartado Postal 380, Tegucigalpa.
Hong Kong	Swindon Book Co., 13-15 Lock Road, Kowloon.
Iceland	Snaebjörn Jónsson and Co. h f., Hafnarstraeti 9, P.O. Box 1131, Reykjavik.
India	Oxford Book and Stationery Co., Scindia House, New Delhi; 17 Park Street, Calcutta.
Indonesia	P.T. Gunung Agung, 6 Kwitang, Djakarta.
Iran	Iran Book Co. Ltd., 127 Nadershah Avenue, P.O. Box 14-1532, Tehran; Economist Tehran, 99 Sevom Esfand Avenue, Tehran (sub-agent).
Iraq	National House for Publishing, Distributing and Advertising, Rashid Street, Baghdad.
Ireland	The Controller, Stationery Office, Dublin.
Israel	Emanuel Brown, P.O. Box 4101, 35 Allenby Road and Nachlat Benyamin Street, Tel Aviv; 9 Shlomzion Hamalka Street, Jerusalem.
Italie	Distribution and Sales Section, Food and Agriculture Organization of the United Nations, Via delle Terme di Caracalla, 00100 Rome; Libreria Scientifica Dott. L. De Biasio "Aeiou", Via Meravigli 16, 20123 Milan; Libreria Commissionaria Sansoni "Licosa", Via Lamarmora 45, C.P. 552, 50121 Florence.
Jamaica	Teachers Book Centre Ltd., 96 Church Street, Kingston.
Japan	Maruzen Company Ltd., P.O. Box 5050, Tokyo Central 100-31.
Kenya	The E.S.A. Bookshop, P.O. Box 30167, Nairobi.
Korea, Rep. of	The Eul-Yoo Publishing Co. Ltd., 5 2-Ka, Chong-ro, Seoul.
Liban	Dar Al-Maaref Liban S.A.L., place Riad El-Solh, B.P. 2320, Beyrouth.
Luxembourg	Service des publications de la FAO, M. J. De Lannoy, rue du Trône 112, 1050 Bruxelles (Belgique).
Malaysia	MPH Distributors Sdn. Bhd., 71/77 Stamford Road, Singapore 6 (Singapore).
Maroc	Librairie "Aux Belles Images", 281 avenue Mohammed V, Rabat.
Mauritius	Nalanda Company Limited, 30 Bourbon Street, Port-Louis.
México	Dilitsa, Puebla 182-D, Apartado 24-448, México 7, D.F.
Netherlands	N.V. Martinus Nijhoff, Lange Voorhout 9, The Hague.
New Zealand	Government Printing Office: Government Bookshops at Rutland Street, P.O. Box 5344, Auckland; Mulgrave Street, Private Bag, Wellington; 130 Oxford Terrace, P.O. Box 1721, Christchurch; Princes Street, P.O. Box 1104, Dunedin; Alma Street, P.O. Box 857, Hamilton.
Nicaragua	Culturama, Camino de Oriente, Apartado 4741, Managua.
Nigeria	University Bookshop Nigeria Ltd., University of Ibadan.
Norway	Johan Grundt Tanum Bokhandel, Karl Johansgt. GT 41-43, Oslo 1.
Pakistan	Mirza Book Agency, 65 The Mall, Lahore 3.
Panamá	Distribuidora Lewis S.A., Edificio Dorasol, Calle 25 y Avenida Balboa, Apartado 1634, Panamá 1.
Perú	Librería Juan Mejía Baca, Azangaro 722, Lima.
Philippines	The Modern Book Company, 928 Rizal Avenue, Manila.
Poland	Ars Polona-Ruch, Krakowskie Przedmiescie 7, Warsaw.
Portugal	Livraria Bertrand, S.A.R.L., Apartado 37, Amadora; Livraria Portugal, Dias y Andrade Ltda., Apartado 2681, Rua do Carmo 70-74, Lisbon - 2.
Rep. Dominicana	Fundación Dominicana de Desarrollo, Casa de las Gárgolas, Mercedes 4, Santo Domingo.
Roumanie	Ilexim, Calea Grivitei No. 64-66, P.O. Box 2001, Bucharest.
Saudi Arabia	Khazindar Establishment, King Faysal Street, Riyadh.
Singapore	MPH Distributors Sdn. Bhd., 71/77 Stamford Road, Singapore 6.
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Sri Lanka	M.D. Gunasena and Co. Ltd., 217 Norris Road, Colombo 11.
Suisse	Librairie Payot S.A., Lausanne et Genève; Hans Raunhardt, Kirchgasse 17, Zurich 1.
Sweden	C.E. Fritzes Kungl. Hovbokhandel, Fredsgatan 2, 103 27 Stockholm 16.
Tanzania	Dar es Salaam Bookshop, P.O. Box 9030, Dar es Salaam.
Thailand	Suksapan Panit, Mansion 9, Rajadamnern Avenue, Bangkok.
Togo	Librairie du Bon Pasteur, B.P. 1164, Lomé.
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United States of America	UNIPUB, 650 First Avenue, P.O. Box 433, Murray Hill Station, New York, N.Y. 10016.
Uruguay	Juan Angel Peri, Alzaibar 1328, Casilla de Correos 1755, Montevideo.
Venezuela	Blume Distribuidora S.A., Calle 3, N° 508, Quinta Palmera Sola, Campo Alegre, Chacao, Caracas.
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